

Simulation-Based Evaluation and Recommended Guidelines for the VLCS *Royal Princess*

Proposed Operations in Southeast Alaskan Pilotage Waters, 2019



Figure 1: Royal Princess simulation model. Photo courtesy of Captain Levi Benedict ©.

Prepared by the Southeast Alaska Pilots Association

Based on Simulations Conducted at Alaska Vocational Technical College (AVTEC), Seward, Alaska December 8–13, 2018

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Change Sheet

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Disclaimer

The research and findings in this report reflect the cooperative work product of the SOUTHEAST ALASKA PILOTS' ASSOCIATION (SEAPA) and HOLLAND AMERICA GROUP (HAG). This report, and the safe operational guidelines recommended herein are founded on simulation-based research. The results and findings are based on data accumulated in the process of that research as well as the use of the best available technology and the good faith effort of the participants. The use and application of these safe operational guidelines (Operational Envelope) do not relieve the prudent mariner of the obligation to exercise safe navigational practices and do not hold SEAPA or HAG liable. This report is intended for further consideration by SEAPA and HAG to enact the recommendations contained herein.

Acknowledgements

Many thanks are due to a great many people for their efforts expended in the course of this project. First and foremost, the SEAPA Members, Officers and Board of Directors who committed significant personal funds, personal time and effort in this pursuit of due diligence. Mr. George Burkley of the Maritime Pilots Institute, for not only producing a magnificent simulation model, but also taking-on the monumental task of forging a nonwriter pilot's ideas into this report. SWAPA for jumping in to share the costs of the simulation model, along with the participation of Captains Josh Weston, Brian Vermette, and Jeff Pierce. SEAPA's Captain Jill Russell for taking on the task of administrator for this project, her many hours of preparation, advice and expertise in the field of simulation, and for keeping us all on task during the week of simulation work. The simulation facility AVTEC, in Seward Alaska, for providing a highly professional and excellent facility and support. The SEAPA VLCS (v2) Committee Members -Captains Hans Antonsen, Tomi Marsh, Levi Benedict and Norbert Chaudhary for their significant efforts during the course of this last year. SEAPA Pilots Captains Jeff Baken, Rich Preston, Steve Axelson, Frank Didier, Scott Jones and Kathy Flury for their participation in the simulations. Our industry partners from Holland America Group/Princess Cruises, Captain Tim Stringer, and Captain Alan Wilson. *Royal Princess's* Captain Nick Nash, Staff Captain Allesandro Genzo as well as all the officers and crew. Captain Bill Kennedy, a fellow SEAPA pilot who stepped-up at the last minute to join an observation trip aboard the *Royal Princess* to take part in the simulation model data collection effort. Amak Towing master's, Captain Lonnie Adams, and Captain Mike Korsmo. CLAA agent, Mr. Rick Erickson. USCG COTP Juneau, Captain Steve White, BMP members of the Alaska Marine Board, in particular Mr. Charles Ward and Captain David Artz (AMP), for their interest and strong support.

Introduction

This study is the third in the series of joint simulation-based studies to apprise cruise companies and SEAPA of operational limits and to create safe operating guidelines for VLCS (Very Large Cruise Ships) operating in Southeast Alaska waters. The first study, completed in December of 2017, studied the Norwegian Cruise Lines (NCL) vessel *Norwegian Bliss*. The Norwegian Bliss report may be found on Southeast Alaska Pilots' website.¹ In 2019, SEAPA membership chartered a second VLCS (v2) committee to conduct two additional studies for the Royal Caribbean International (RCI), "Ovation of the Seas", and Princess Cruises "Royal Princess" due to these vessels' pending deployment to Southeast Alaska. This report addresses the findings of these collaborative studies conducted by SEAPA and Princess Cruises/Holland America Group, for our collective work for the *Royal Princess*, recognizing the separate roles with common goals in the effort to "protect life and property, and the marine environment"², in an economically achievable manner.

The primary goal of this simulation-based risk assessment, and corresponding simulation evaluations, was to identify the environmental and operational parameters at which undesirable incidents began to happen, defined by the SEAPA VLCS (v2) Committee as the Edge Of the Comfort Zone (EOCZ). The standard of care used by the Committee as a basis for these recommended guidelines was if a simulation maneuver could be reliably completed by an average Marine Pilot, on an average day, while achieving consistent, above average results. Evaluation scenarios were designed to address the challenging operating maritime environment in Southeast Alaska, including restricted channels, fjords, and bays with unpredictable ice concentrations (from glacial calving); as well as, high winds, large tidal ranges, and strong tidal currents. The Committee utilized a framework closely based on the previous study work for Norwegian Bliss for identifying and evaluating the level of risk for simulated evolutions. The base framework involved: 1) the professional judgment of a senior mariner; 2) the measurement of operating performance according to predetermined risk criteria; 3) a separate, individual debrief interview of the master; 4) a separate individual debrief of the pilot (to assess their perceptions of risk); and 5) correlation, comparison, and resolution of the previous four measures by the Committee as a whole.

Various industry stakeholders observed the simulation efforts during the course of the two studies including (2) Amak Towing Company tug masters, The Captain of the Port (COTP) for US Coast Guard Sector Juneau, Cruise Lines Agencies of Alaska (CLAA), Southwest Alaska Pilots Association (SWAPA), Alaska Marine Pilots (AMP), Hawaii Pilots, The Marine Pilot Coordinator (MPC) for the Alaska Board of Marine Pilots. The stakeholders once again responded favorably to the collaborative efforts of the Committee.

¹ <https://www.seapa.com/>

² AS 08.62.157

Summary

To initiate this study for the Royal Princess, the SEAPA committee engaged in thorough data-gathering for the vessel which included an observation trip in November of 2018 during a 9-day voyage, followed by a week of full-mission simulation conducted at AVTEC in Seward, Alaska, for various Southeastern Alaska ports and waterways.

Simulations were conducted during the week of December 8-13, 2018, by a team made up of nine members of the Southeast Alaska Pilots Association (SEAPA) and two representatives from Princess Cruises/Holland America Group, including Captain Tim Stringer (Regal Princess Master) of a Royal-class Passenger vessel and Captain Alan Wilson (VP Marine, Fleet Operations). The project team completed thirty-seven simulation runs covering four geographic pilotage areas, simulating the most unfavorable and frequent wind and current conditions. The objectives of the simulations were to identify pilotage navigation scenarios which presented challenges for safe operations of the Royal Princess.

Overall the simulations produced serious challenges in wind and current conditions common to the SEAPA Pilotage area. The pilots reported that the Royal Princess model displayed unusually high drift “crab” angles and poor steering response as compared to their everyday safe operation experiences with cruise vessels presently calling in region. This steering response has been described by experienced pilots as ‘similar to a twin-screw single rudder ship but of greater size, at slow speed’³. The recommendations in this study strictly limit port calls and necessitate restricted operating parameters to ensure safe operations of the *Royal Princess* in Southeast Alaska waters.

Figure 2: Cruise Vessel Royal Princess



³ Note, twin propeller ships with a single rudder in-between are known by pilots to steer poorly.

Principal Dimensions - Mega Ship – *Royal Princess*

The Royal Princess is a large passenger vessel of 142,714 Gross Tons, with a length of 1083' (330m), maximum structural beam at the "SeaWalk" of 155' (47m), Air draft of 198.4' (60.5m), and summer-load draft of 29' (8.55m). She is outfitted with conventional propulsion composed of two straight shaft inboard turning propellers (18MW each), conventional - spade rudders, as well as (3) Bow and (3) Stern tunnel thrusters with a combined power reported as 10,134hp at each end. Lateral windage, also known as "sail area" for this vessel is 13,446 square meters. Passenger maximum is 3537, with 1342 crew for a total of 4879. This vessel will be the largest conventional propulsion vessel to date to engage in the Alaskan passenger ship trade.

Figure 3: Royal Princess – Principal Dimensions



Findings

The following findings are based upon simulations of transits in and out of Ketchikan, Tracy and Endicott Arm, Skagway, and Juneau.⁴ Early simulation outcomes influenced the selection of later simulations, as challenge scenarios were identified by the research process. Ice work navigation in the simulation runs were found to be generally typical in ship behavior for this class of vessel and additional study effort for ice transits was limited. Emphasis was focused on transits of the Ketchikan East Channel navigation area vicinity of California and Idaho rocks and North Tongass Narrows vicinity of the shipyard and the airport areas, as well as reduced-speed harbor transits in Ketchikan, Skagway and Juneau.

Primary Findings: From the thirty-seven runs conducted in simulation are:

1. *Royal Princess* exhibits extremely poor low speed handling characteristics. This vessel behavior resulted in extreme difficulty for Pilots to manage directional stability during transits. This poor steering behavior occurred in the commonly encountered conditions of 15 knots wind, and no current. The significant challenges to steer the ship in these conditions during simulation led pilots to engage in emergency ship handling practices to accomplish normal transits. This was of particular note during simulations run in the narrow channels of the Ketchikan area and Tongass Narrows.
2. Minimum steering speed is listed as 4 knots as per the wheelhouse poster. Simulations found that even at speeds of 7 to 8 knots the vessel is extremely sluggish with thrusters often required to maintain or regain positive control of the track of the vessel.
3. The vessel requires speed to turn, with no response to rudders without way on. She has limited to no response to a kick-ahead to turn and displays no ability to impart a “twisting moment” to turn the ship given use of opposite engines and rudders alone.
4. The vessel displays unusually high crab-angles in moderate crosswind and cross current conditions, providing scant allowance for any single-point failure, or even minor distraction in piloting maneuvers.
5. Due to the vessel’s thruster limitations and poor low-speed steering capabilities, slow approaches and berthing maneuvers in the port areas were generally impaired given moderate winds of 20 knots and current velocities of 1 to 2 knots.
6. The vessel’s thrusters are effective to hold the ship, dead in the water, given beam wind conditions of 25-27 knots or less without consideration for current.
7. The ship behavior results of these simulations are similar to those provided by Princess Cruise Lines for other ports the vessel currently calls upon.⁵

⁴ Due to simulation capabilities, ice transit simulations were conducted in Tracy and Endicott Arm as a substitute for Yakutat/Glacier Bay operations

⁵ Carnival Corporation studies use a computer “track pilot” to guide vessels during simulation research. Study results of computer-guided vessels in simulation and human pilot-guided vessels in simulation are noted as not equivalent by the SEAPA Pilots.

Findings: Use of Tugs

A study utilizing tractor tugs to control the Royal Princess was concurrently conducted by SEAPA pilots, with input from experienced tug operators, to evaluate the use of tractor tugs to mitigate risk to ports particularly for VLCS class vessels. Because of the diminished handling characteristics for this particular VLCS vessel, the tractor tug study found that even the conventional tugs presently in region were of benefit in lower environmental conditions to improve handling of the Royal Princess and to meet SEAPA's standards of care. The report recommends a minimum of two 70-ton bollard pull (BP) tractor tugs be deployed to the ports of Ketchikan, Juneau and Skagway. Tugs of this capability are not available in the region with only one tractor tug in region estimated to have a 50-ton BP rating. All other tugs in region are conventional propulsion (significant reduction in capability to assist) with a maximum estimated rating of 33-ton BP.

Findings: Known Limitations of Simulation

The SEAPA Pilots recognize that simulation is an excellent tool for general studies and is valuable for informing the decision process. SEAPA also recognizes that simulations, both this current AVTEC effort and the efforts conducted by others in the port studies prepared by Princess Cruise Lines, have inherent limitations in the reliance on mathematical models and assumptions that may be incongruent with actual wind, currents, ship behavior and other intangible factors experienced in actual operations.

Findings: Request for Additional Onboard Data

To clarify and mitigate these concerns, the SEAPA Pilots have requested a selection of actual on-board data to assure the Royal Princess can be operated in Southeast Alaskan waters according to a general standard of care. SEAPA expects that the response from Princess will include graphical track plots of the vessel transiting similar-sized narrow, windy, and high current areas, with the corresponding ship data of crab angle, vessel speed, wind and current conditions, and the engine and rudder orders used to maintain positive and safe control of the vessel.

The SEAPA Pilots extend their thanks for the participation and support from Princess Cruises/Holland America Group, in the conduct of this important research. The study team agreed it was a privilege to be able to participate in these simulations, and that this process is an essential part of fostering the safety of navigation and the protection of the environment, people and property of the State of Alaska.

Figure 4: Simulation Image of the Royal Princess Model



Simulation Debrief Notes – Navigation and Controllability

1. The vessel has side-thruster power capable to maneuver to a maximum of 25-27 knots of wind on her beam (Design criteria – 25kn)
2. At a speed through the water of approximately 10 knots, the ship carries between 9° and 12° of crab angle given 20-25kn of beam wind.
3. Steering the vessel with current abaft the beam of velocity greater than 1kn given ship's speed through the water of 7 knots or less causes her to become sluggish in her steering, requiring hard over rudder and kicks ahead.
4. The vessel is docked in the final 2-3 meters to a berth using closed circuit cameras due to the stowed position of lifeboats overhanging the side of the ship. Direct visual sightline of the berthing line is impeded for the final approach alongside.
5. The vessel has a 76.4m blind zone ahead only visible to the conning officer by using a ('dolphin') camera.⁶
6. The vessel's bulbous bow is exceptionally long, projecting nearly to the furthest extension of the bow on deck.
7. When the ship is dead in the water, the bow thrusters are stronger in their effect on the vessel's behavior than the stern thrusters.
8. The rudders may be used fully during high speed astern maneuvers.
9. At speeds of 4 to 5 knots astern the vessel will "answer" to her rudders at an angle of 15 degrees.⁷
10. For vessel slow down maneuvers at harbor speeds, the Royal Princess requires 50% power astern or greater for the engine power to be effective in slowing the ship.
11. The crew typically do not maneuver the vessel in tight areas using the computer "Track Pilot" as the system has a tendency to "drag the stern" in turns. The captain (*Regal Princess*) reports he uses manual steering for critical maneuvers.
12. The vessel has two wind speed anemometers, one forward and one aft. The aft unit is particularly useful during backing maneuvers.
13. The typical method to maneuver the Royal Princess in other ports (outside of Alaska) is to maintain a higher harbor transit speed of 7 to 8 knots and then to sharply back the ship in the vicinity of the berth. This maneuver is used to avoid transiting at slower 4-6 knots which is a speed that the ship is sluggish and impaired in her steering.
14. The Royal Princess is reported to use the services of escort tractor tugs in other ports. Interviews of various PCL Masters state this is necessary in winds of 20 knots or greater.
15. The Royal Princess is equipped with escort-rated chocks and bollards for center-lead forward and center-lead aft escort towing services. Bollard pull rated for 75 tons as reported by VP Marine Ops.

⁶ "dolphin" camera and blind zones noted on vessels Pilot Card.

⁷ "Answering to her rudders" means that the ship will follow the direction of the rudder angle. Note: many ships do not respond to their rudders when going astern.

Recommendations

Given the outcome of the simulations and review of reports conducted by Princess Cruises of other port areas, the following recommendations are offered by SEAPA:

1. Request a selection of actual on-board data to assure the *Royal Princess* can be operated in Southeast Alaskan waters according to the general standard of care.
 - a. Response will include graphical track plots of the vessel transiting similar-sized narrow channel, windy, and high current areas, with the corresponding ship data of crab angle, speeds, wind and current conditions and the engine, thruster and rudder orders used to maintain positive and safe control of the vessel. These must be verified to be accomplished in hand steering. Stockholm and Oslo (Drobak Narrows) were suggested during team simulation discussions.
2. Recommend against any port entry at Ketchikan until SEAPA VLCS Committee review of actual ship operational data, from the above request, confirms and establishes safe operational envelope parameters.
3. If safe operational parameters are confirmed by the VLCS SEAPA Committee for *Royal Princess* to allow port calls to Ketchikan, strict adherence to operational envelope guidelines is recommended particularly in regard to rerouting arrivals via the Guard Island Pilot Station. See, Figure 6:Operational Envelope –
4. Guidelines for the Operational Envelope are intended as a baseline for operational limits between SEAPA pilots and Masters of the *Royal Princess* for the 2019 cruise season. The intent is to actively monitor and revise the proposed guidelines as appropriate for safe operations. Additionally, the Committee intends to apply feedback from the actual *Royal Princess* to more completely tune the hydrodynamic model, if warranted.
5. A debrief with SEAPA and Princess Cruises/Holland America Group, should be conducted following the initial 2019 season to reevaluate and edit the Operational Envelope guidelines based on the actual operation data from Southeast Alaska transits and maneuvers.

Addendum to Recommendations

The VLCS committee submitted feedback on recommendations directly to PCL via teleconference and email in early February, prior to the completion of the final report. This feedback specifically addressed concerns related to the VLCS committee's study recommendations, which advised against 'any entry for the port of Ketchikan'. This recommendation as a result of study findings indicating poor handling characteristics at low speeds in the approaches to the harbor. The SEAPA President and VLCS Lead met with PCL/HAG at the Fleet Operation Center (FOC) in Seattle in mid-March to review Neptune data from two actual ship transits, one for a transit to the port of Oslo, and the other to the port of Stockholm. These two runs, reviewed at the FOC, failed to provide conclusive data within the parameters requested to confirm safe operational limits for the port of Ketchikan. HAG/PCL provided further data the final week of March to SEAPA, which the VLCS Committee reviewed. Although a majority of this data also failed to fall within the requested range (beam

winds of 15+ knots, ship speed 7 knots or less, etc.), nor could all equipment parameters be evaluated, one data set fell within the requested parameters. Captain Tim Stringer was able to run a ‘drift test’ with the Regal Princess along with the resultant table of data provided in figure 5 below. During the course of the final week of March, the VLCS Committee was able to compare with drift angles/swept path observed during the Royal Princess ship ride, simulation study runs, and the ‘drift study’ results provided by Captain Stringer to confirm study conclusions for recommending safe operational envelope limits.

Figure 5 - Drift Test results from Regal Princess



The reported 8° to 9° drift angles in the wind range of 15 knots was found to comport well with study findings. This is backed up by Captain Stringer’s reported experience that this class of vessel exhibits 8° swept path in 15 knots beam wind. Using the swept path table provided in the pilot card for Royal Princess, this concludes at 8° the effective beam width is 84.3m. Maximum clearance for the channel between California and Idaho Rocks in Tongass Narrows East Channel is ~ 154m. This yields a resultant (70m/2=35m) 35 meters clearance to the grounding line from bow and stern with ship centered precisely mid-channel during transit. Accounting for residual swept path due to ‘slide’ from the approach turn at South Pennock Island presumed swept path is expected to be ~ 100m thus reducing clearance to ~ 27m on each side during transit. Port of Ketchikan operational limits were thus revised by the VLCS Committee as shown in figure 6 – Operational Envelope for 2019 Season – *Royal Princess*, maximum 15 knots wind. These limits will be jointly reevaluated in a meeting to be scheduled following initial visits to Ketchikan based on experience gained from these transits, and data collected from actual transits in region. In separate correspondence, SEAPA has requested initial port call transits for both entry and departure be made via N. Tongass Narrows with pilot boarding at Guard Island. Additional request has been made to USCG Captain of the Port for various measures to reduce single point failure distractions to ship navigation crew and pilots to mitigate risk for safety of transit.

SEAPA Operational Envelope – Guidelines for 2019 Season

Figure 6: Operational Envelope – 2019

Holland America Group and Southeast Alaska Pilots Association DRAFT- Operational Envelope for M/V Royal Princess - DRAFT 2019 Cruise Season		
"What We Can Do Without Compromising Safety"		
General Considerations	The Master and Pilot will jointly assess the current, wind speed & direction, visibility, navigational hazards (e.g., channel limitations, density of ice, anchored vessels) to agree on an abort point or to proceed. For port calls where the winds are forecast to exceed 45 knots for any time during the port call the Master and Pilot will jointly address the port capabilities to include at a minimum: berth limitations (e.g., bollard strength, number and arrangements of bollards); ship's mooring limitations (e.g., max number of lines, line strength); port resources (e.g., tug availability and horsepower) in consideration of port cancellation.	
	AREA	WIND
Ketchikan Area	Tongass Narrows East Channel (California and Idaho Rocks)	15 Knots
		15 Knots
	Ketchikan Berth 4 Docking	15 Knots
	Ketchikan Berth 4 Undocking	15 Knots
	Tongass Narrows Ketchikan Harbor to Lewis Reef (Airport / Drydock Area)	15 Knots
		15 Knots
Ice Areas	Yakutat Bay/Disenchantment Bay (Hubbard Glacier)	For Evolutions where actual or forecast winds are 25 knots or greater, the Master and Pilot will jointly assess the current, wind direction, visibility, waterway limitations (including size & density of ice, marine mammals, etc.), and presence of other vessels to agree on an abort point or to proceed.
	Glacier Bay	
	Endicott Arm	For Evolutions where actual or forecast winds are 25 knots or greater, the Master and Pilot will jointly assess the current, wind direction, visibility, waterway limitations (including size & density of ice, marine mammals, etc.), and presence of other vessels to agree on an abort point or to proceed.
	Tracy Arm	Advise against any entry into Tracy Arm
Juneau Area	Juneau FKL Docking	20 Knots
		25 Knots
	Juneau FKL Undocking	20 Knots
		25 Knots
Skagway Area	Skagway RRA/RRF Docking	25 Knots
	Skagway RRA/RRF Undocking	25 Knots

Analysis of Simulations by Port Area

Ketchikan Area Simulations

Figure 7: Ketchikan Area Chart



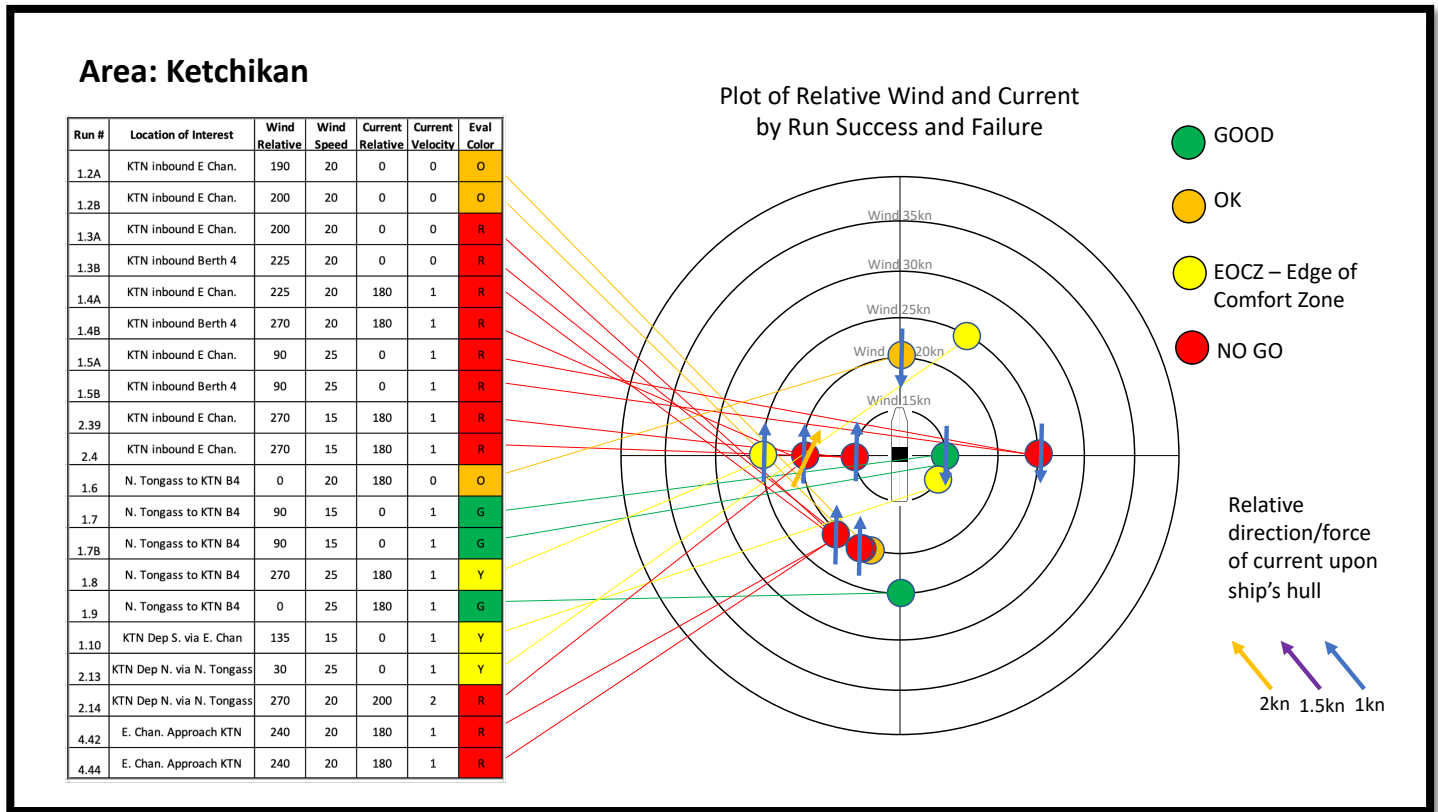
Description of Ketchikan Area

Ketchikan is a major port area for Southeast Alaska. It is accessed from sea via Revillagigedo Channel or Clarence Strait thence Nichols Passage or Tongass Narrows that provides three entrances to the port. The Port of Ketchikan has free tidal stream communication from the Northwest and Southeast of the port areas via the Tongass Narrows. The Eastern approaches in Tongass Narrows are termed the “East Channel”, the Northern approaches are termed the “North Channel”. West Channel is not used by large vessels. Simulations were conducted for the port of Ketchikan in both Tongass Narrows approach channels and in the harbor area for docking scenarios.

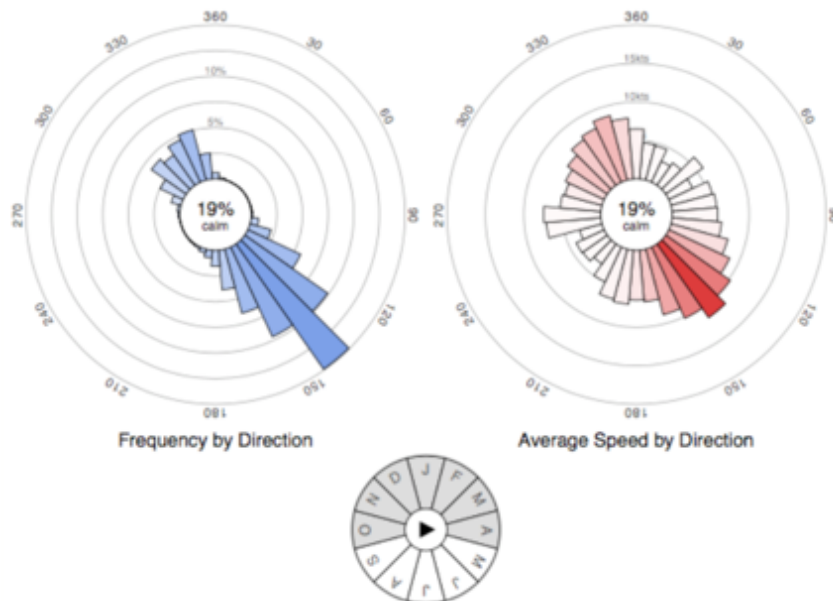
Three areas of concern were highlighted in the Ketchikan simulations. The first concern noted (and primary in the study) was the 150m wide passage in the Tongass Narrows between California and Idaho rocks. Second concern was the constricted channel between the (Revillagigedo Island) shipyard and (Gravina Island) airport, and slower speed transits of the Ketchikan harbor area given high winds and adverse currents resulting in significant swept path.

The transit scenarios in the Ketchikan area correlate well to similar areas of Southeast Alaska waters for critical analysis of overall performance by the *Royal* class throughout. Time limitations did not allow for study of all ports and channel transits.

Figure 8: Ketchikan – Analysis of Vessel Relative Wind and Current Conditions per Simulation Run



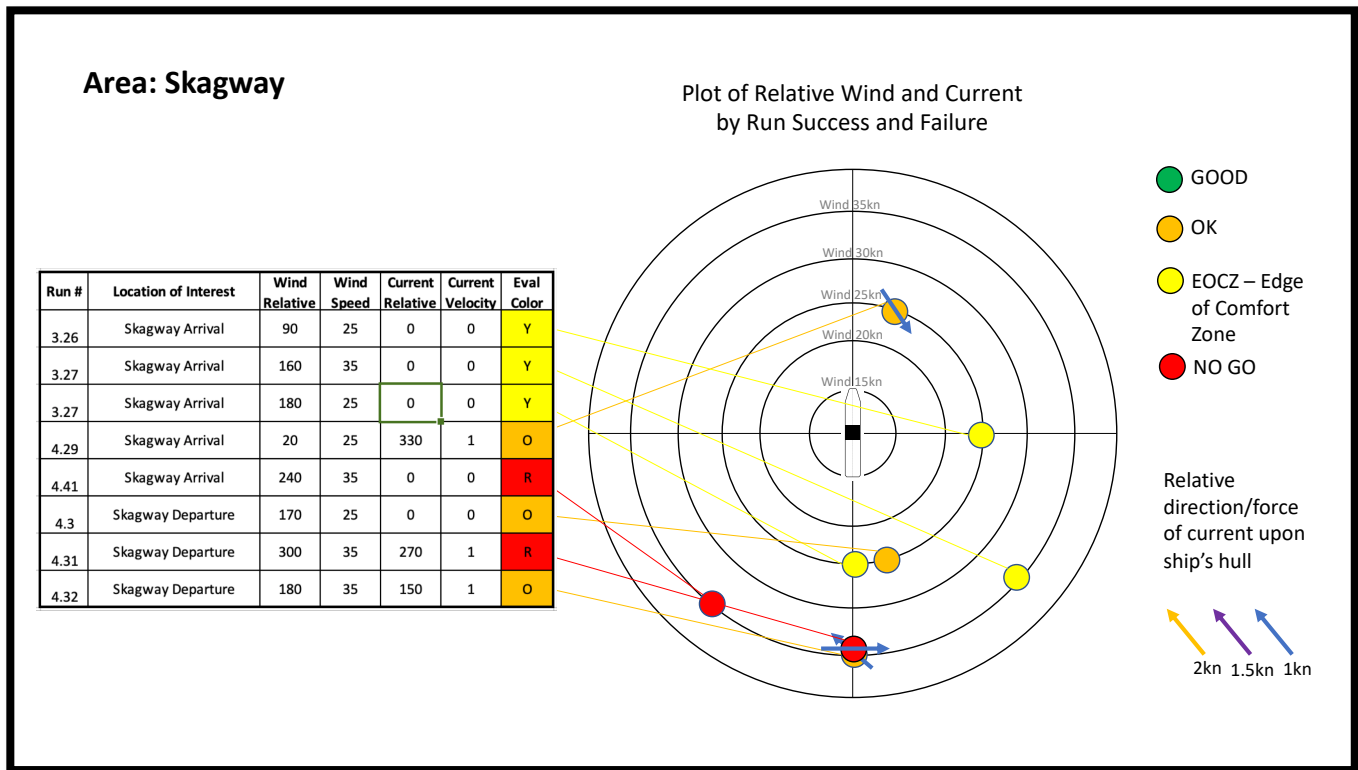
PAKT: Ketchikan International Airport



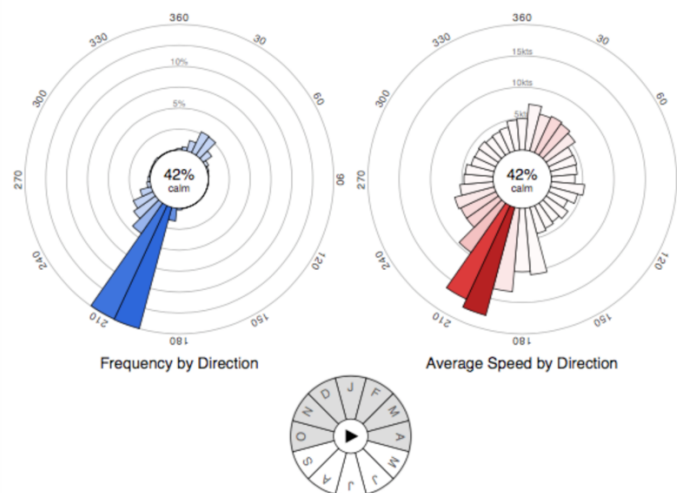
Skagway Area Simulations

For the Skagway area simulations, loss of positive control of the vessel and hazardous maneuvering occurred when the prevailing wind and current was high, (particularly at or above 30knots) and in the astern quadrants with following or crossing currents. The vessel was generally easier to control with head wind and current conditions.

Figure 9: Skagway - Plot of Relative Wind and Current per Simulation Runs



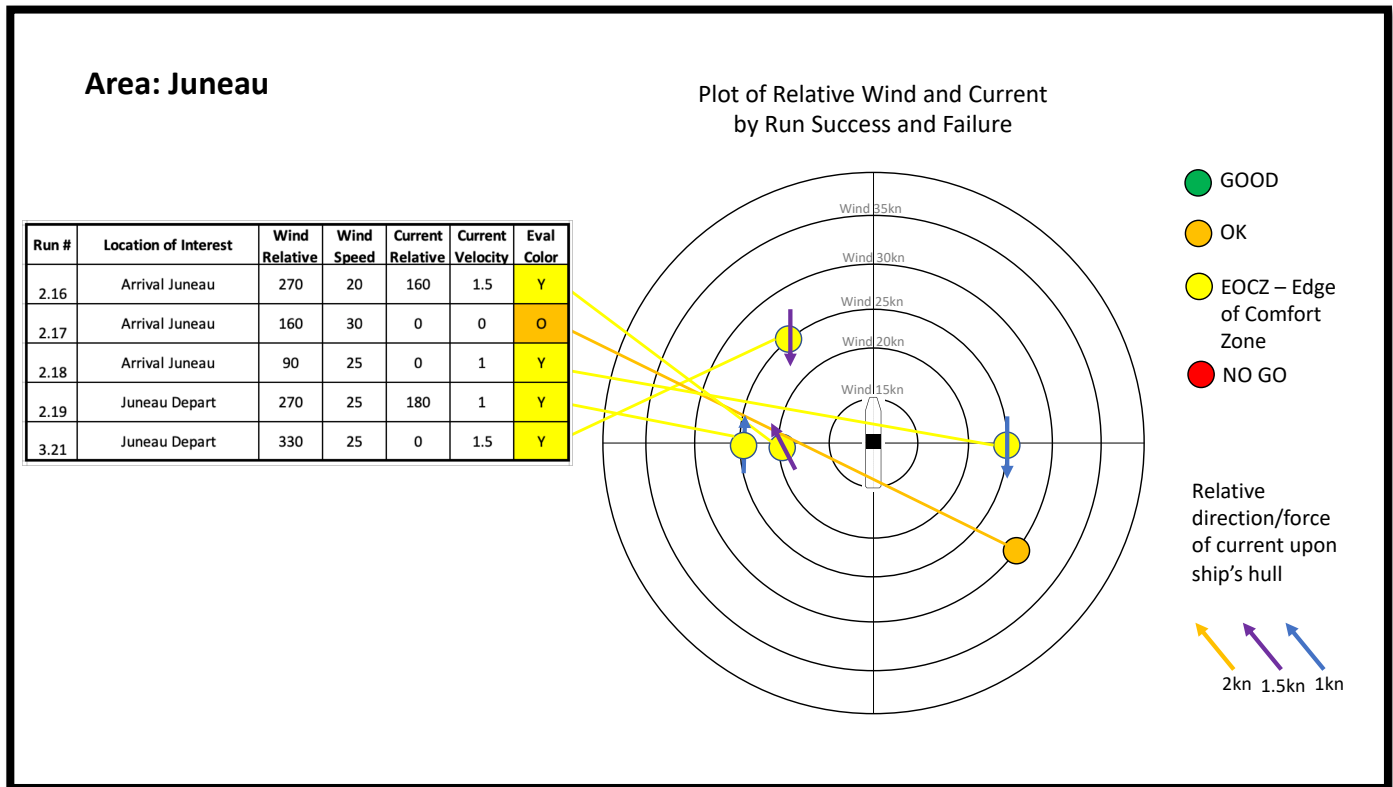
PAGY: Skagway Airport



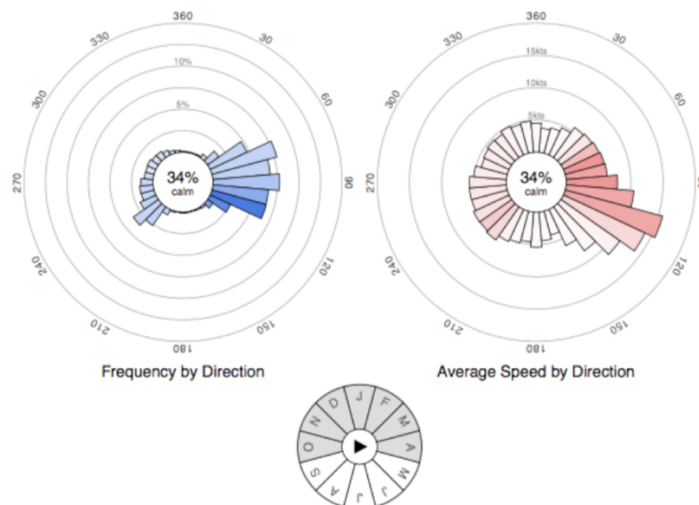
Juneau Area Simulations

For the Juneau area simulations, the vessel was found to be in the “edge of the comfort zone” for the testing pilots given ahead wind conditions and all-around currents. The only example of a satisfactory simulation outcome is when the vessel was maneuvered in zero current conditions.

Figure 10: Juneau - Plot of Relative Wind and Current Per Simulation Runs



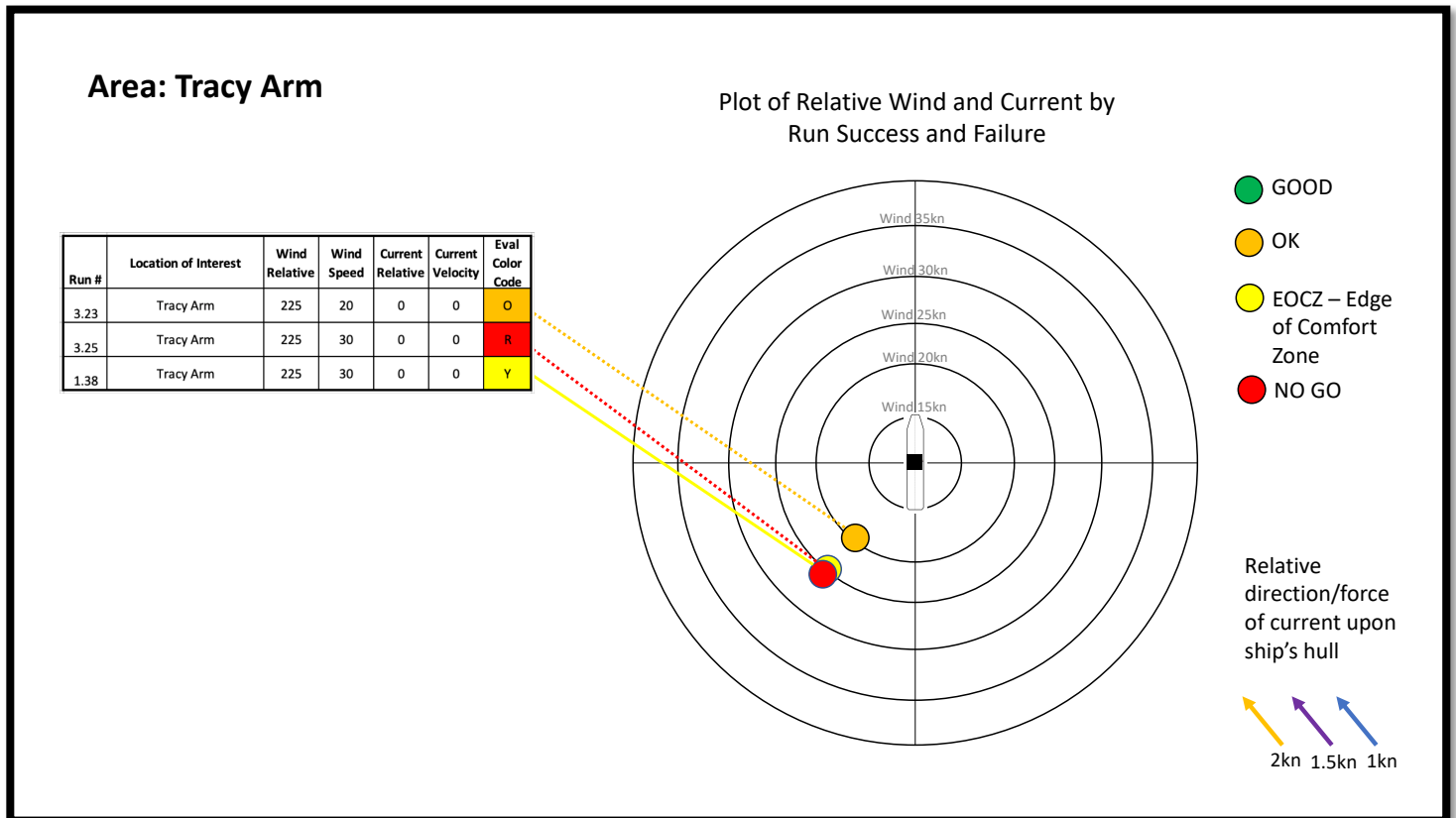
PAJN: Juneau International Airport



Tracy Arm Area Simulations

Three Tracy Arm area simulations – to simulate ice area transits (Endicott Arm, Glacier Bay, and Yakutat Bay) resulted in data demonstrating unsatisfactory vessel controllability with high winds on the port quarter. Currents were not factored into the Tracy Arm simulations.

Figure 11: Tracy Arm - Plot of Relative Wind and Current by Simulation Runs



Simulation Run Log

Figure 12: Simulation Run Log

ROYAL PRINCESS - Run Log						
Run	Run-Loc-dir-Day.Tot	Run?	Port/Berth/Area	Wind	Current	Location
12/9	2-ECH-arr-1.2	☐	Arr Ketchikan/4/S	SE 20	none	Mtn Point
12/9	3-ECH-arr-1.3	☐	Arr Ketchikan/4/S	SE 25	none	Mtn Point
12/9	4-ECH-arr-1.4	☐	Arr Ketchikan/4/S	SW 20	Flood 1kt	Mtn Point
12/12	42-ECH-arr-4.42	☐	Arr Ketchikan/4/S	SW 20	Flood 1kt	Mtn Point
12/12	42-ECH-arr-4.44	☐	Arr Ketchikan/4/S	SW 20	NONE	Mtn Point
12/10	5-ECH-arr-1.5	☐	Arr Ketchikan/4/S	NE 25	Ebb 1kt	Mtn Point
12/10	39-ECH-arr-2.39	☐	Arr Ketchikan/4/S	SW 15	Flood 1kt	Mtn Point
12/10	40-ECH-arr-2.40	☐	Arr Ketchikan/4/S	SW 15	Flood 1kt	Mtn Point
12/10	6-KTN-arr-1.6	☐	Arr Ketchikan/4/N	SE 20	Ebb 1kt	Channel Is
12/10	7-KTN-arr-1.7B	☐	Arr Ketchikan/4/N	SW 15	Flood 1kt	Lewis Rf
12/11	8-KTN-arr-1.8	☐	Arr Ketchikan/4/N	NE 25	Ebb 1kt	Lewis Rf
12/11	9-KTN-arr-1.9	☐	Arr Ketchikan/4/N	SE 25	Ebb 1kt	Lewis Rf
12/11	10-ECH-dep-1.10	☐	Dep Ketchikan/4/S	SW 15	Flood 1kt	Berth 4
12/11	13-KTN-dep-2.13	☐	Dep Ketchikan/4/N	SE 25	Flood 1kt	Berth 4
12/11	14-KTN-dep-2.14	☐	Dep Ketchikan/4/N	SW 20	Flood 2kt	Berth 4
12/11	16-JNU-arr-2.16	☐	Arr Juneau/FKL-AS	SE 20	Flood 1.5kt	JNU ISL
12/11	17-JNU-arr-2.17	☐	Arr Juneau/FKL-AS	SE 30	none	JNU ISL
12/11	18-JNU-arr-2.18	☐	Arr Juneau/FKL-AS	NE 25	Ebb 1kt	JNU ISL
12/11	19-JNU-dep-2.19	☐	Dep Juneau/FKL-AS	NE 25	Ebb 1kt	FKL
12/11	21-JNU-dep-3.21	☐	Dep Juneau/FKL-AS	SE 25	Flood 1.5kt	FKL
12/9	22-END-IB-3.22	☐	Endicott Arm Bar	none	Ebb 2 kts	Bar approach
12/9	37-END-IB-1.37	☐	Endicott Arm Bar	None	Ebb 4 kts	Bar approach
12/9	23-END-OB-3.23	☐	Endicott Arm Bar	SE 20	Ebb 4 kts	Bar approach
12/9	24-TAS-OB-3.24	☐	Tracy Arm S-turns	20kt	none	S-turns OB
12/9	25-TAS-OB-3.25	☐	Tracy Arm S-turns	30kts	none	S-turns OB
12/9	38-TAS-OB-1.38	☐	Tracy Arm S-turns	30kts	none	S-turns OB
12/12	26-SKG-arr-3.26	☐	Arr Skagway/RRF	SE 25	none	Taiya Inlet
12/12	27-SKG-arr-3.27	☐	Arr Skagway/RRF	SE 35	none	Taiya Inlet
12/12	28-SKG-arr-3.28	☐	Arr Skagway/RRF	SW 25	none	Taiya Inlet
12/12	29-SKG-arr-4.29	☐	Arr Skagway/RRF	NE 25	Ebb 0.5kts	Taiya Inlet
12/12	41-SKG-arr-4.41	☐	Arr Skagway/RRF	SW 35		Taiya Inlet
12/12	30-SKG-dep-4.30	☐	Dep Skagway RRF	SE 25	none	RRF
12/12	31-SKG-dep-4.31	☐	Dep Skagway RRF	NE 35	Ebb 1kt	RRF
12/12	32-SKG-dep-4.32	☐	Dep Skagway RRF	SW 35	Flood 1kt	RRF
12/8	34-SP-NB-4.34	☐	Snow Pass N/B	none	Flood 3.5 kts	Nesbitt Rf
12/8	35-SP-SB-4.35	☐	Snow Pass S/B	SW 25	Flood 3.5 kts	Round Is
12/8	36-SP-SB-4.36	☐	Snow Pass S/B	SE 25	Ebb 2 kts	Round Is
				1 - NO GO	12	
				2 - EOCZ	12	
				3 - OK	10	
				4 - GOOD	3	
Total Simulations:		37				

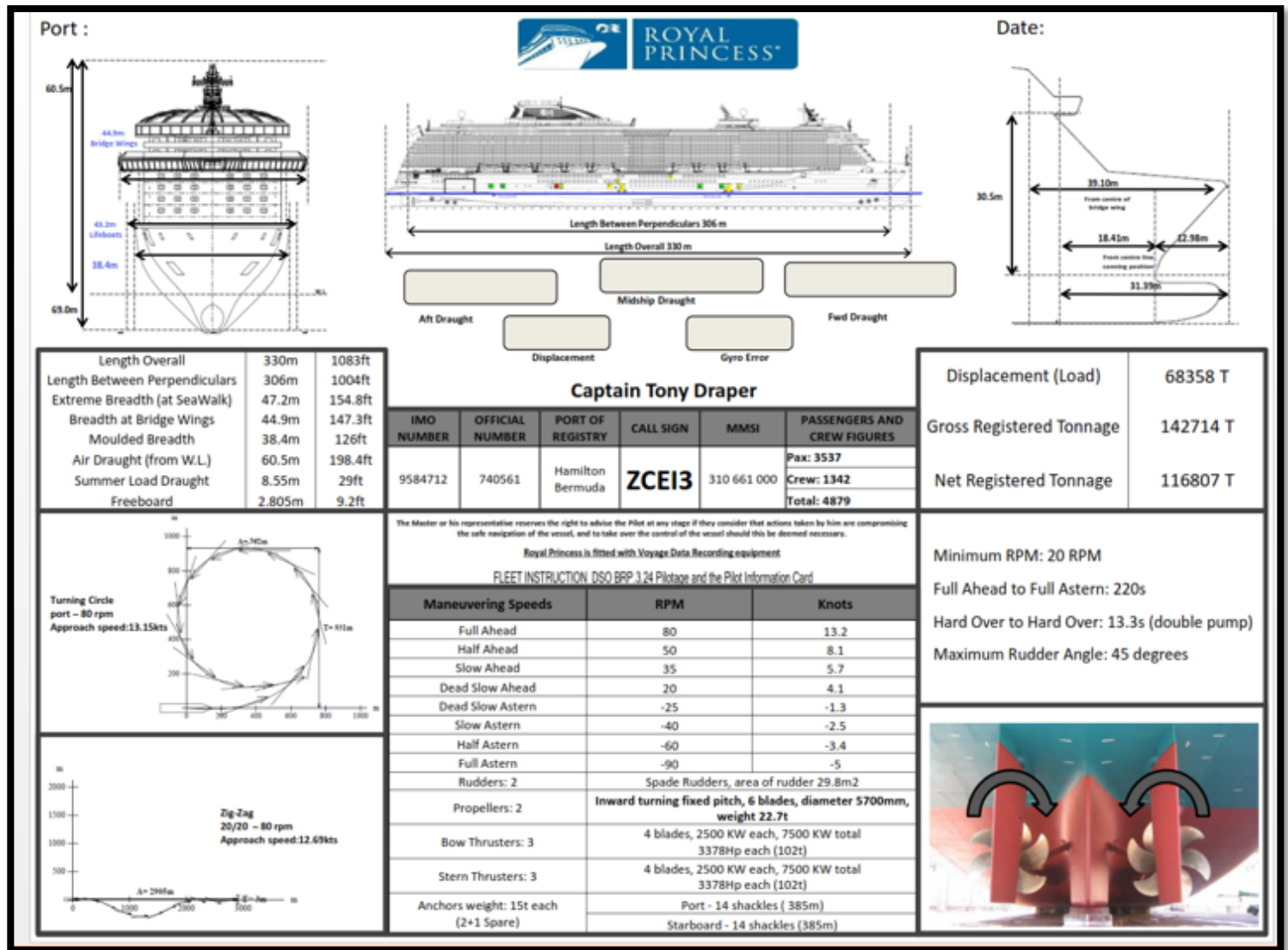
Note for Simulation Run Log Ratings: Ratings 3 & 4 are operationally manageable risk, 2 is at or beyond the upper limit of risk, and 1 is unacceptable risk. Edge of Comfort Zone (EOCZ is rating 2) is defined as: 'the environmental and operational parameters at which undesirable incidents began to happen'.

Simulation Criteria

#	Item	Standard
1	Ketchikan – Mt Point to Saxman	12 knots by Southeast Alaska Vessel Waterway Guide (VWG)
2	Ketchikan – Saxman to Channel Island	7 knots by CFR reference
3	Ketchikan - Harbor	5 knots by Tongass Waterway Guide and VWG
4	Juneau – Dupont to Sheep Creek	14 knots - VWG
5	Juneau – Sheep Creek to Juneau Isle	10 knots - VWG
6	Juneau – Juneau Isle to Rock Dump	7 knots - VWG
7	Juneau - Harbor	5 knots - VWG
8	Maximum drift angle passing through California and Idaho Rocks	7 degrees
9	Thrusters use for vessel control during channel transits (vessel not maneuvering near berth areas)	Thruster use not a common practice for channel transit
10	Tug use	Evaluated in concurrent study

Pilot Card: Royal Princess⁸

Figure 13: Pilot Card, Royal Princess (page 1 of 3)



⁸ Pilot Card Data Provided by Princess Cruise Lines

Figure 14: Pilot Card, Royal Princess (page 2 of 3)

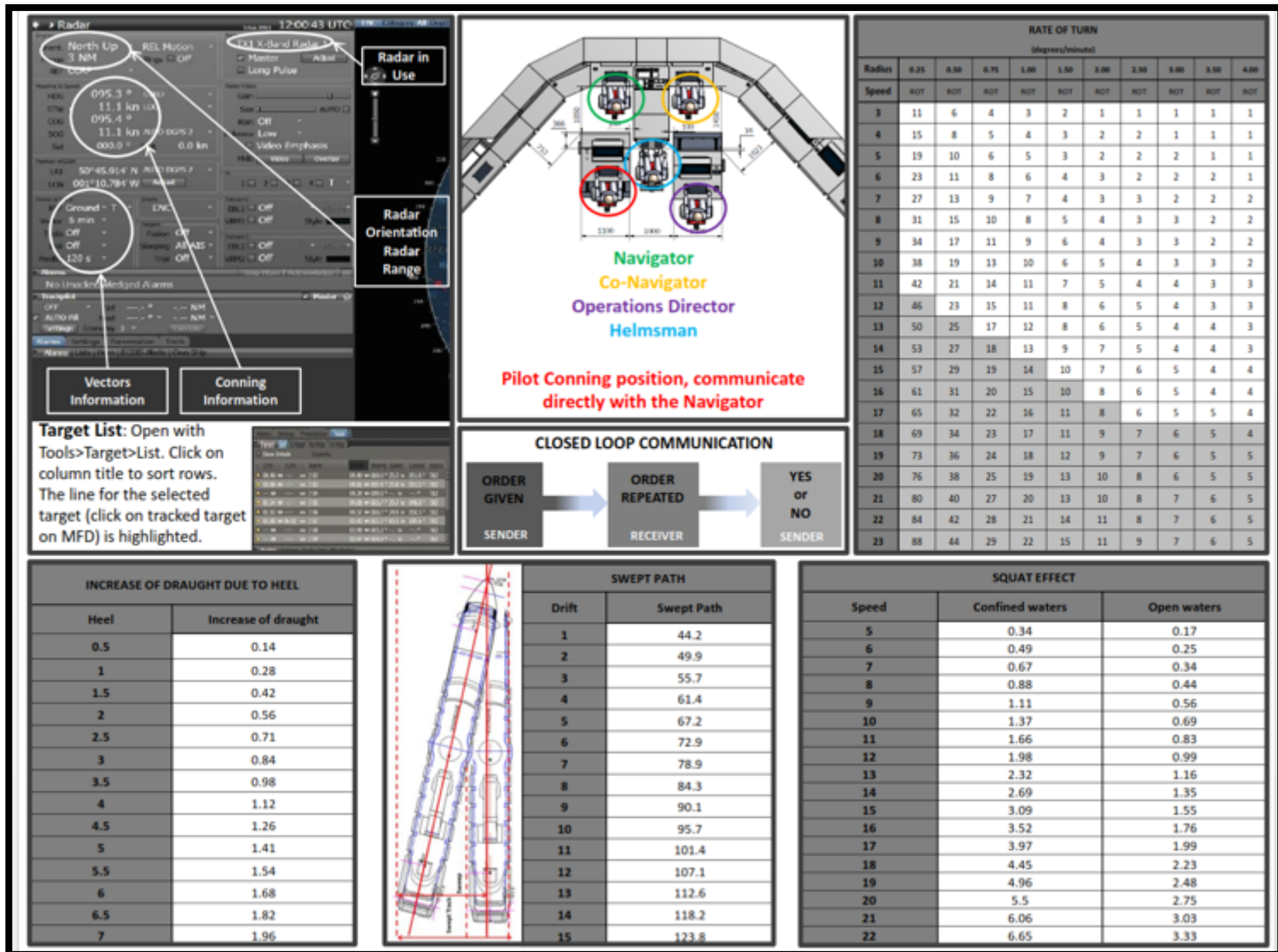
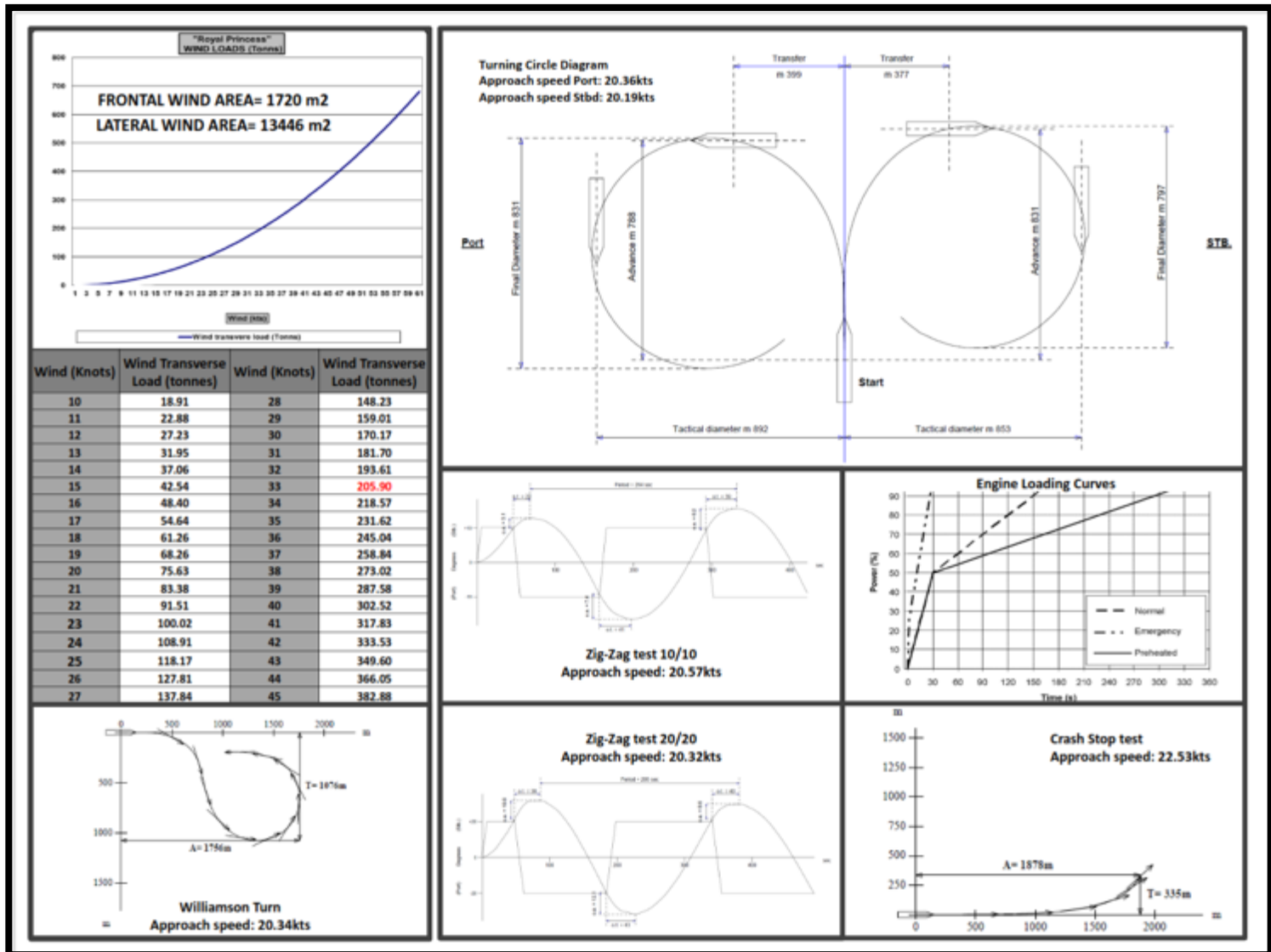


Figure 15: Pilot Card, Royal Princess (page 3 of 3)



Wheelhouse Poster, Royal Princess⁹

Figure 16: Wheelhouse Poster, Royal Princess

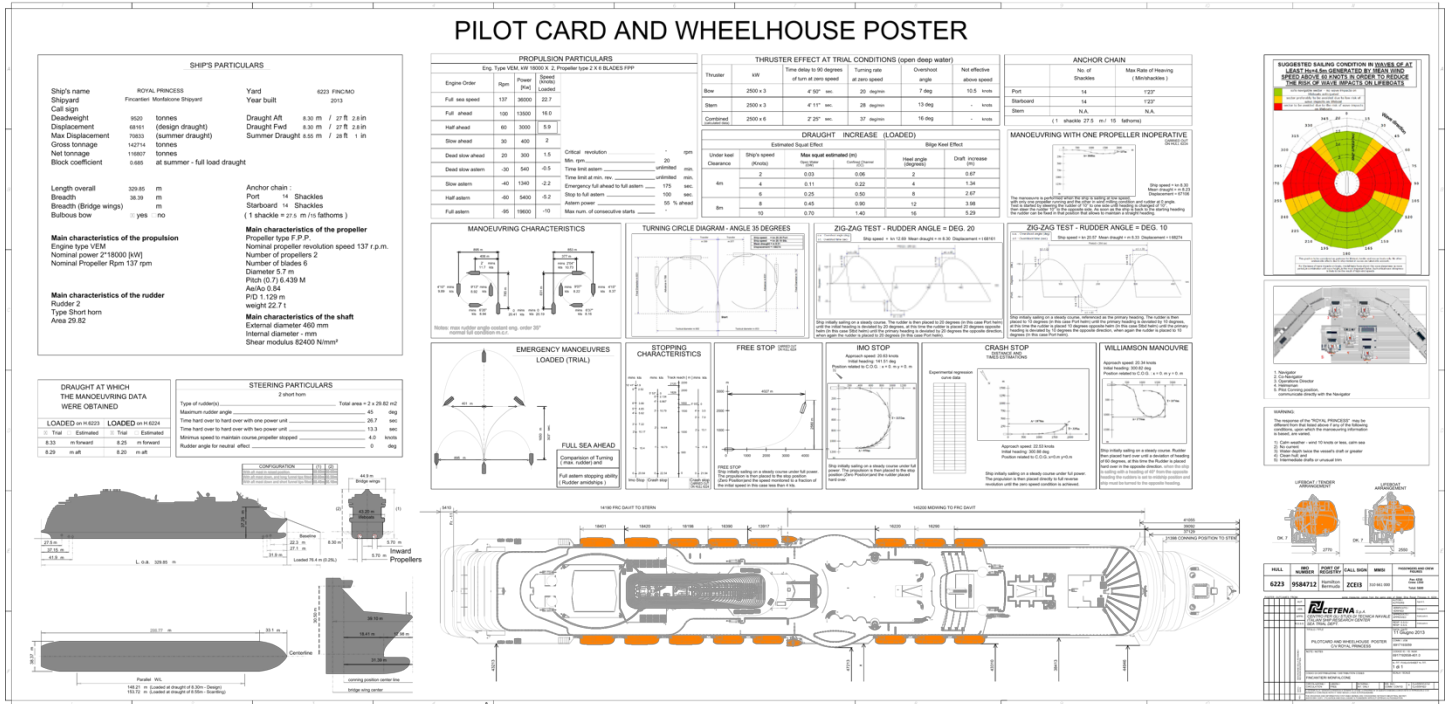


Figure 17: Royal Princess, Alongside at Night



⁹ Wheelhouse Poster data provided by Princess Cruise Lines

Notes Regarding Simulation Vessel Model and Behavior

The ship simulator was programmed with a hydrodynamic model of the *Royal Princess* developed from two data sources. The first data source used was information provided by Princess Cruises/Holland America Group, including the vessel pilot card, maneuvering booklet and data regarding propellers and static stability figures noted in reports provided. The second source of information was gathered during a 9-day observation ride aboard Royal Princess arranged courtesy of HAG and conducted by SEAPA pilots. *Royal Princess's* actual operating behaviors were observed and recorded, in close coordination with the onboard ship's master and officers and by the two SEAPA pilots during all dockings and un-dockings and ship maneuvers. During this effort the vessel's conning screen was video-captured by time lapse photos to record engine, steering, thruster particulars, and environmental data and the pilots concurrently recorded the navigation data using their portable piloting software. This data was then collated and transcribed into spreadsheets for later vetting use in the simulator. The pilots also interviewed the Captain, Staff Captain and senior officers, thus collecting notes based on their expertise for tuning the model behavior. The model was tuned using a Kongsberg full mission ship simulator and its behavior was vetted and reconfirmed with onsite vetting at AVTEC prior to the simulations using data points from both actual information gathered on board, and that found in studies, ship documents, and notes.

The model behavior vetted to within 5% of the stated values on the pilot card, including the turn circle, zig-zag and windage values. The model, in the full mission ship simulator, was then tuned to replicate acceleration/deceleration and turn maneuvers recorded by the pilots aboard the actual ship. The final tuning item was thruster power which was tuned by adjusting the efficiency of the thruster coefficients in order balance the thruster force against 25-27kn of beam wind while the vessel is dead in the water.

Comments during simulations from the attending Master of the Regal Princess (sister ship to the Royal Princess) were that the model is overall "good", and a bit "conservative", being more difficult to pilot than the actual ship. He believed that the model did not lose inertia and slow as fast as the actual ship. Thus, in his opinion, the model carried her way farther, made turns slower and generally reacted slower than the actual ship. The attending pilots noted this assessment by the Master and agreed that the model is likely conservative in behavior, concluding that these minor differences did not impair their use of the model as a tool for the purpose of this simulation effort.

Pilot Card, Simulation Vessel, Royal Princess

Figure 18: Pilot Card, Kongsberg Model, Ship Simulator

PILOT CARD

MROYALF
Version 1


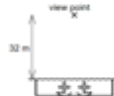
Ship's name Royal Princess Date

Call Sign Deadweight 0 tonnes Year built 2013

Draught aft 8.55 m / 28 ft 9 in Forward 8.55 m / 28 ft 9 in Displacement 88358 tonnes

SHIP'S PARTICULARS

Length overall <u>330</u> m	Anchor chain: Port <u>14.0</u> shackles Starboard <u>14.0</u> shackles
Breadth <u>38.4</u> m	Stem <u> </u> shackles
Buttress bow <u>Yes</u>	(1 shackle = 27.432 m = 15 fathoms)

PROPULSION PARTICULARS

Type of engine Electric Maximum power 37462 kW (50834 hp)

Manoeuvring engine order	RPM	Pitch	Speed (knots)	
			Loaded	Ballast
Full astern speed	-1	-143.4		
Full ahead	9.5	90.0	22.2	
Half ahead	8.5	50.0	13.2	
Slow ahead	6.25	35.0	8.1	
Dead slow ahead	0.125	20.0	5.7	
Dead slow astern	-0.125	-20.0	4.1	
Slow astern	-6.25	-40.0		
Half astern	-8.5	-50.0		
Full astern	-1	-90.0		

Time lost astern min/sec

Full ahead to full astern min/sec

Max. No. of consecutive starts

Minimum RPM knots

Astern power % ahead

STEERING PARTICULARS

Type of rudder Normal Maximum angle 45 °

Hard-over to hard-over 13.3 s

Rudder angle for neutral effect 0 °

Thruster: Bow 7455 kW (10136 hp) Stern 7455 kW (10136 hp)

CHECKED IF ABOARD AND READY

Anchors <input type="checkbox"/> Whistle <input type="checkbox"/> Radar <input type="checkbox"/> 3 cm <input type="checkbox"/> 10 cm ARPA <input type="checkbox"/> Speed log <input type="checkbox"/> Doppler: Yes / No Water speed <input type="checkbox"/> Ground speed <input type="checkbox"/> Dual-echo <input type="checkbox"/> Engine telegraphs <input type="checkbox"/> Steering gear <input type="checkbox"/> Number of power units operating <input type="checkbox"/>	Indicators: <input type="checkbox"/> Rudder <input type="checkbox"/> Rpm/tach <input type="checkbox"/> Rate of turn <input type="checkbox"/> Compass system <input type="checkbox"/> Constant gyro error <u> </u> ° VDR <input type="checkbox"/> Elec. pos. fix. system <input type="checkbox"/> Type <u> </u>
--	--

OTHER INFORMATION:

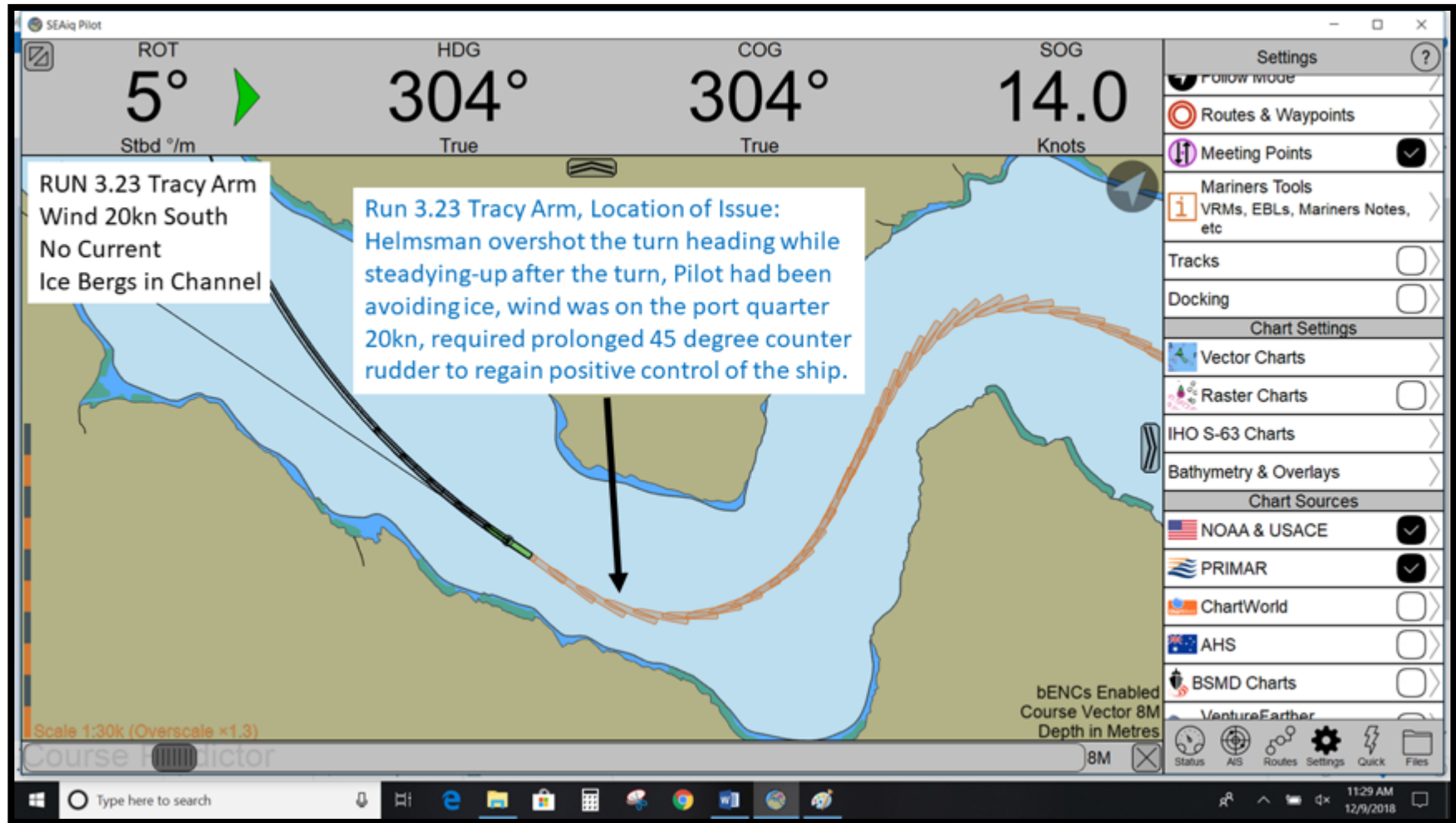
Appendix A:

Simulation Run Screenshots

Screenshots (SEAIq Pilot – PPU) were collected during simulations as means for discussion/debrief for the VLCS study group. They are provided herein as a visual record of the simulation work.

Run 3.23: Tracy Arm

(Moderate ice not shown on this PPU screenshot)



Run 3.25: Tracy Arm

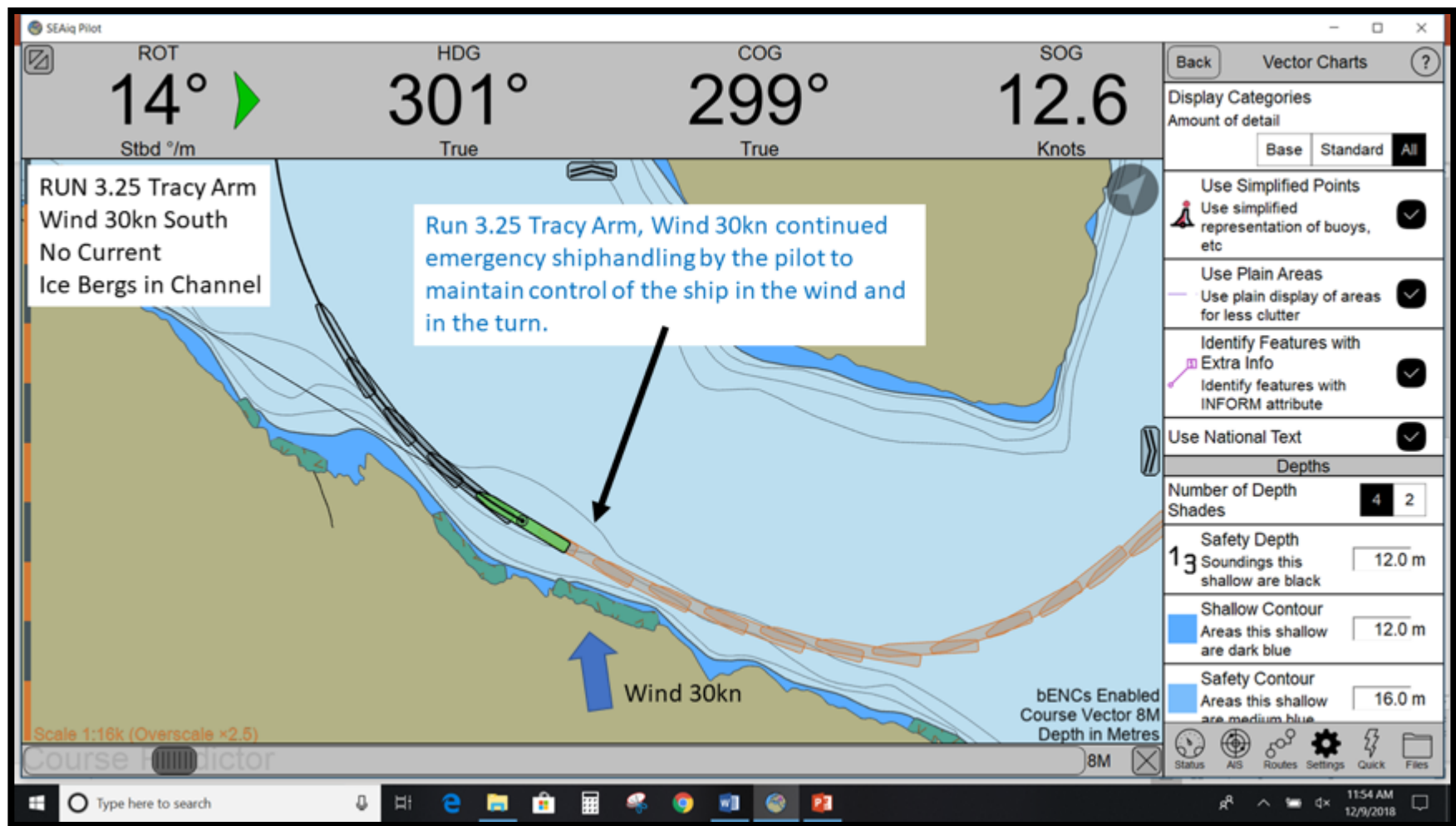
3.25 Tracy Arm, 30kn

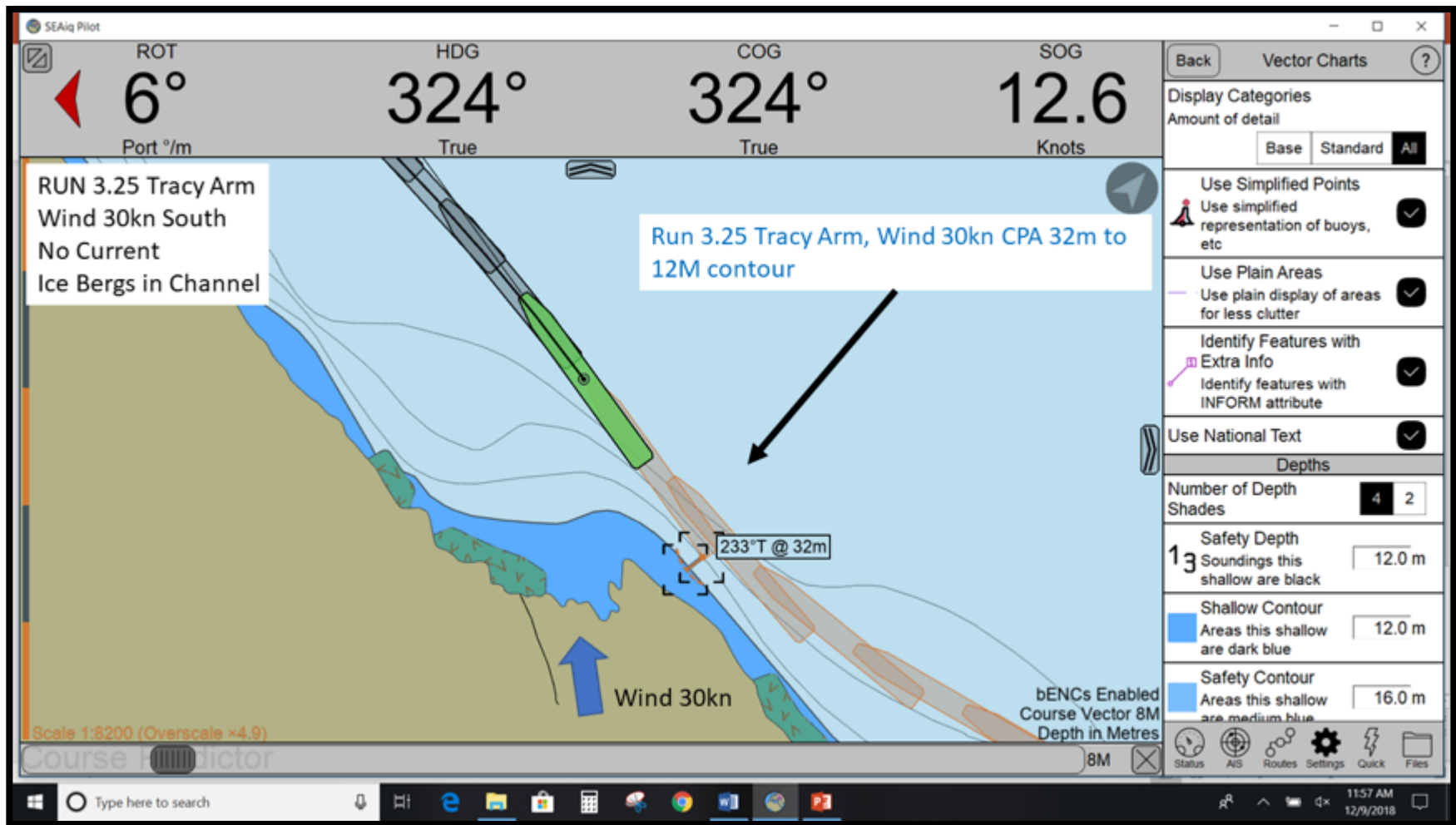
Sunday 12/9/2018

2nd run

Run 3.25: Tracy Arm





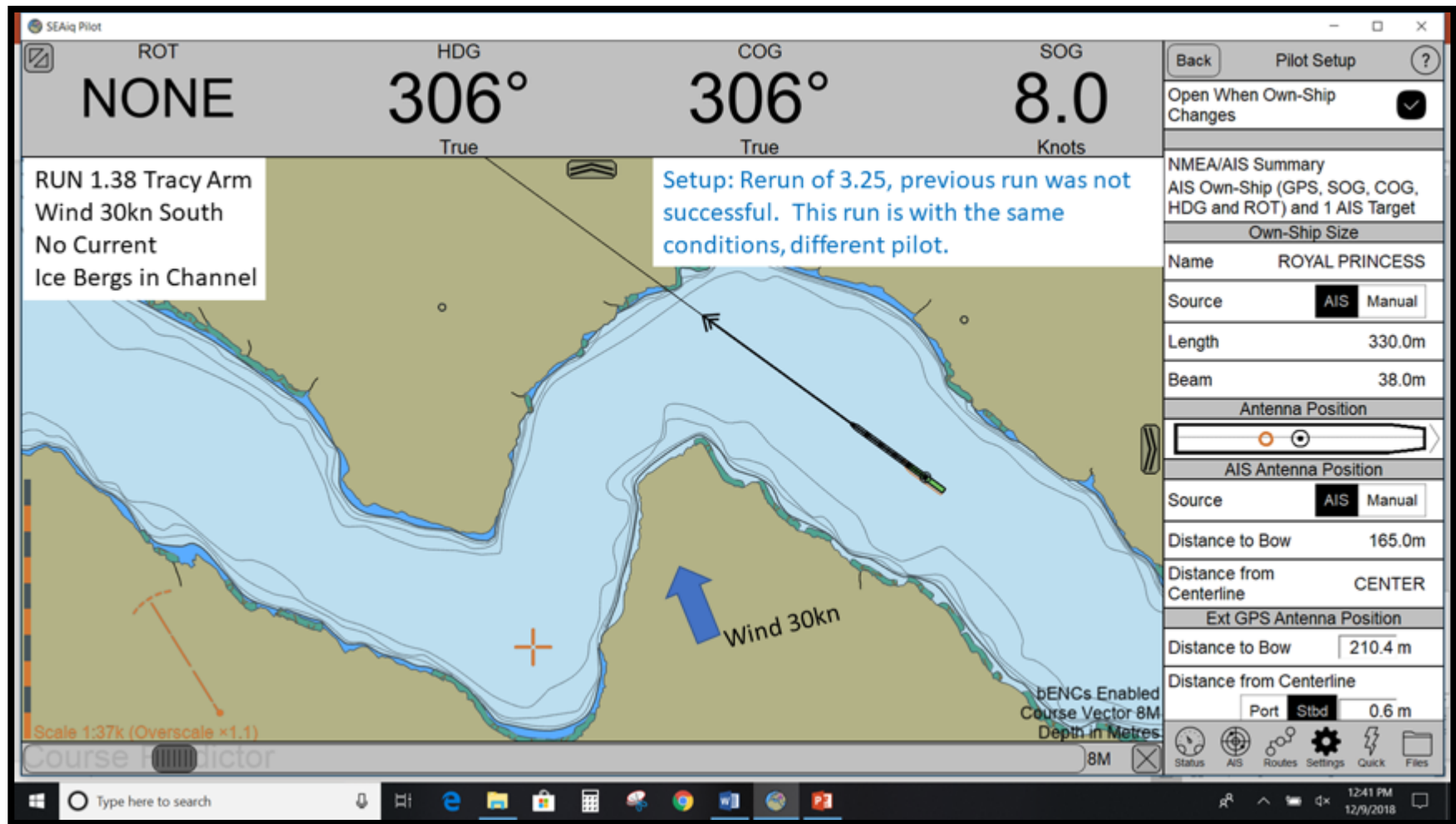


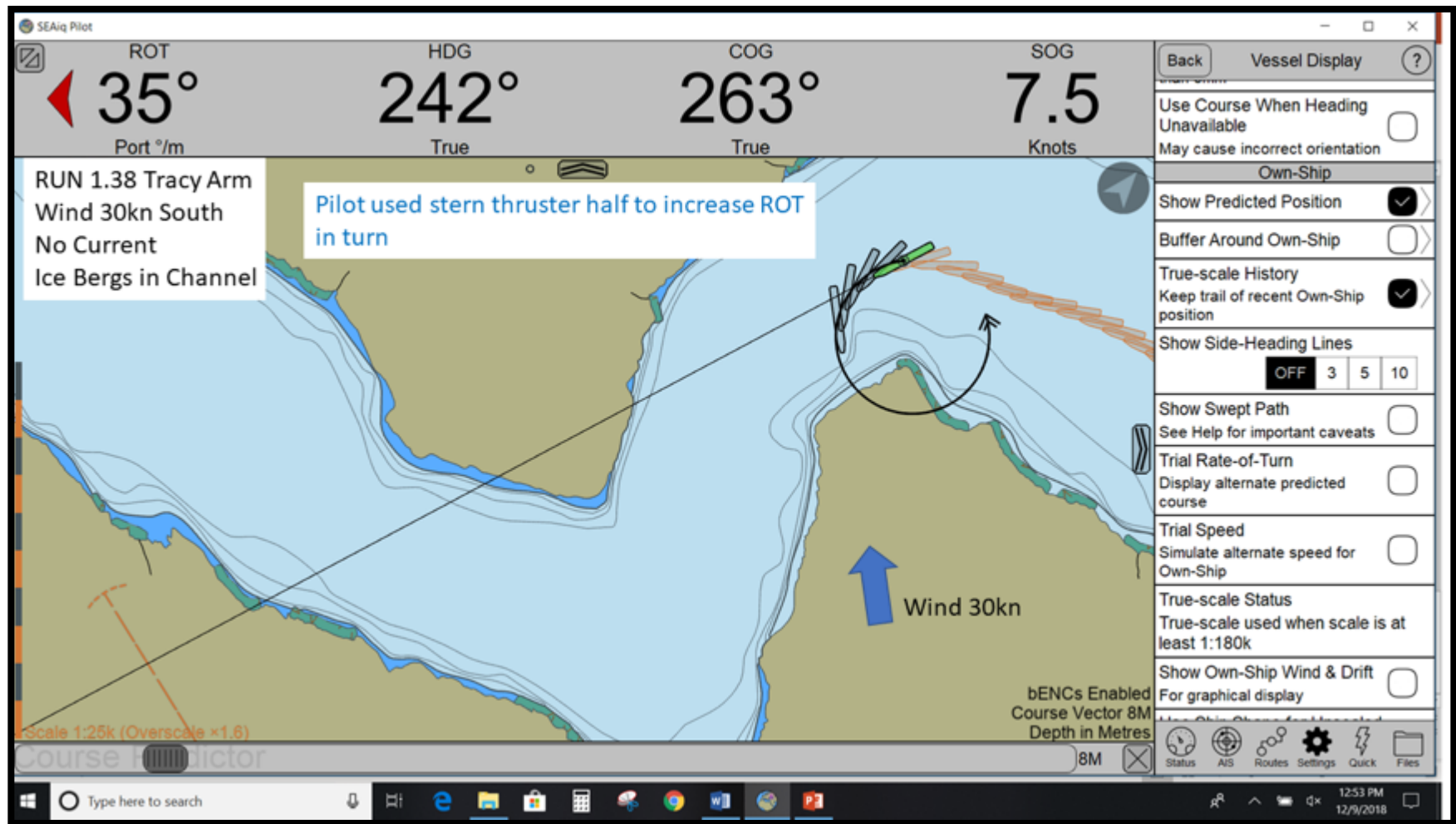
Run 1.38: Tracy Arm

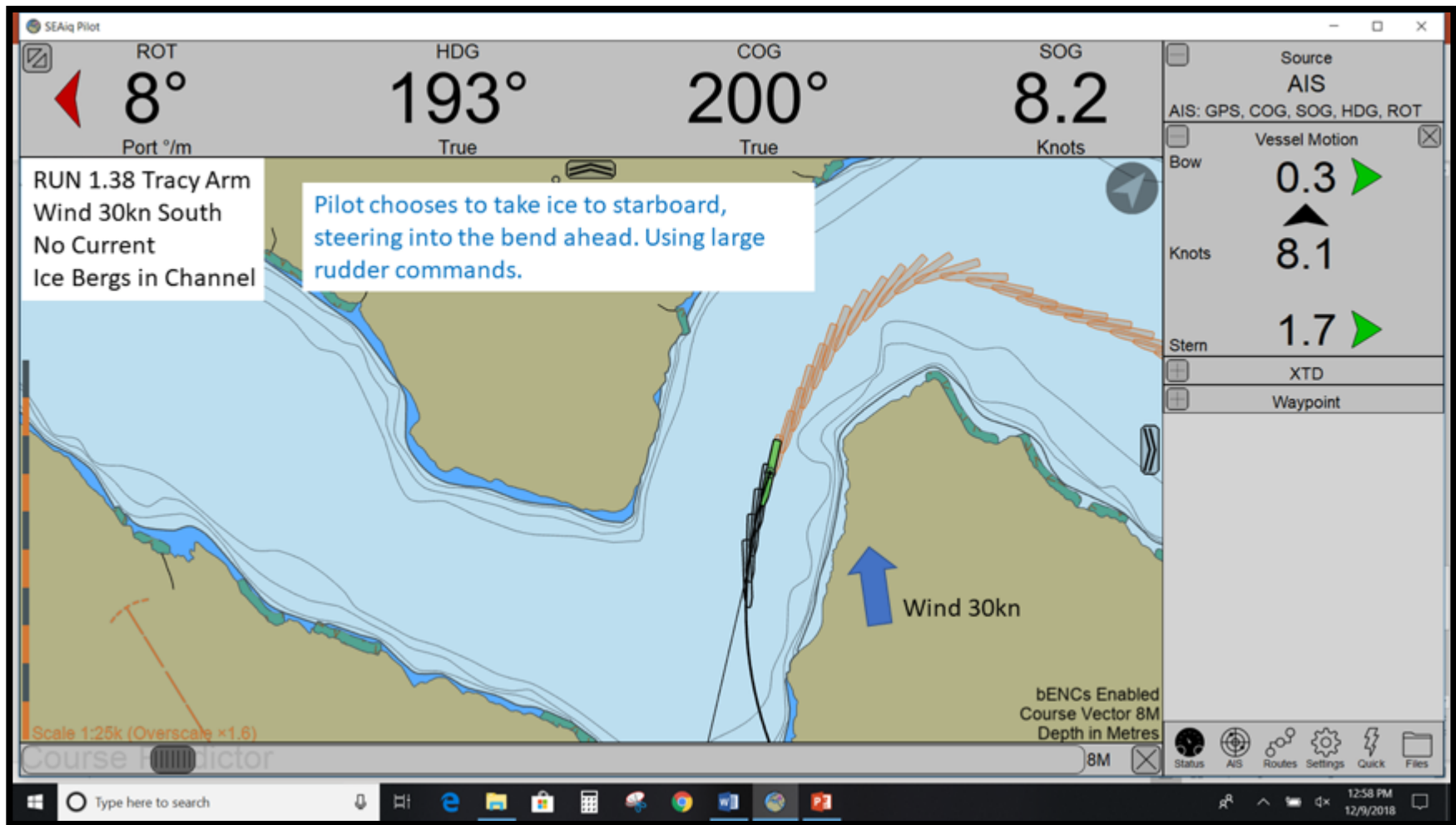
1.38 Rerun of Tracy Arm 30kn

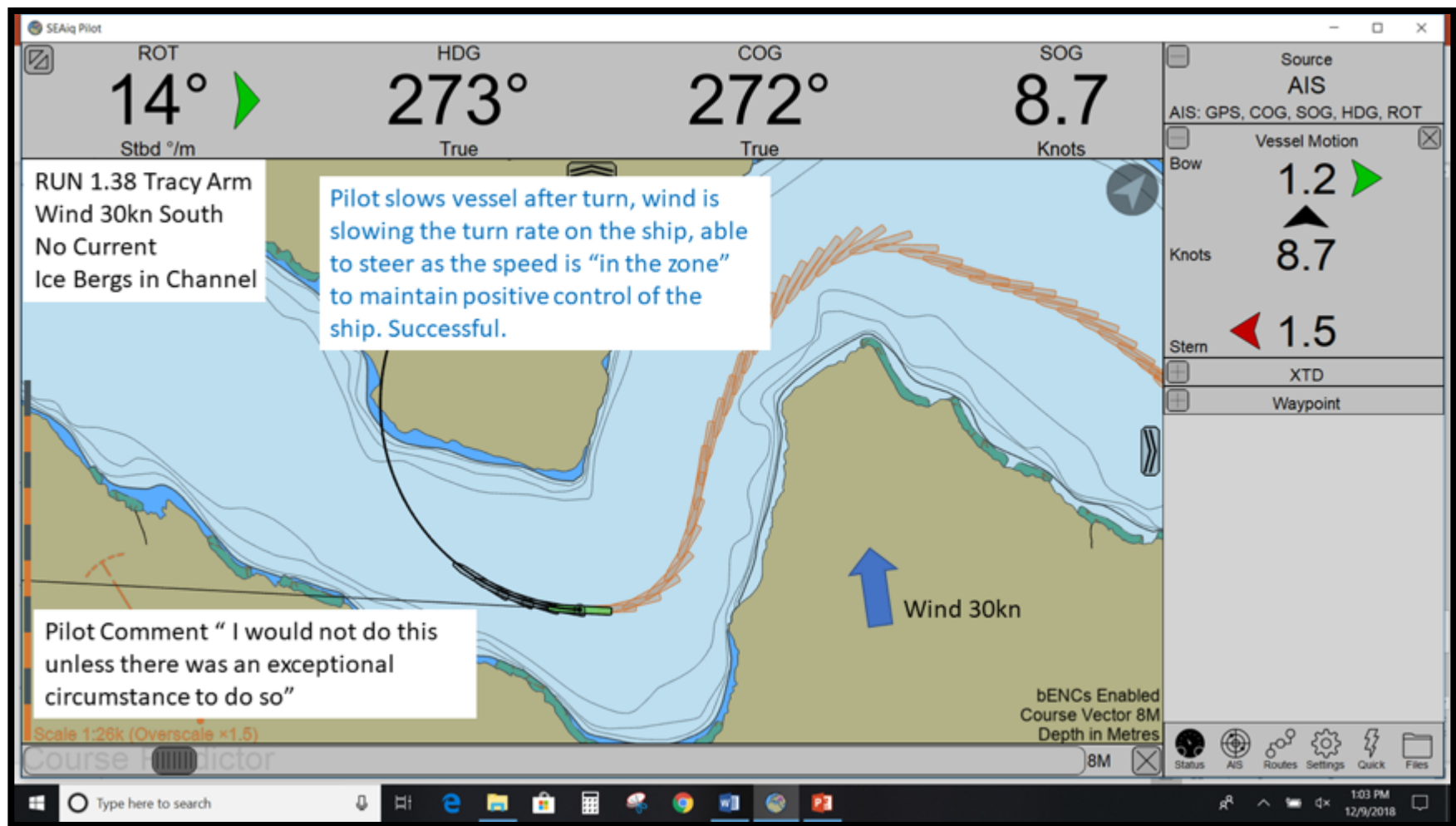
Sunday 12/9/2018

3rd run







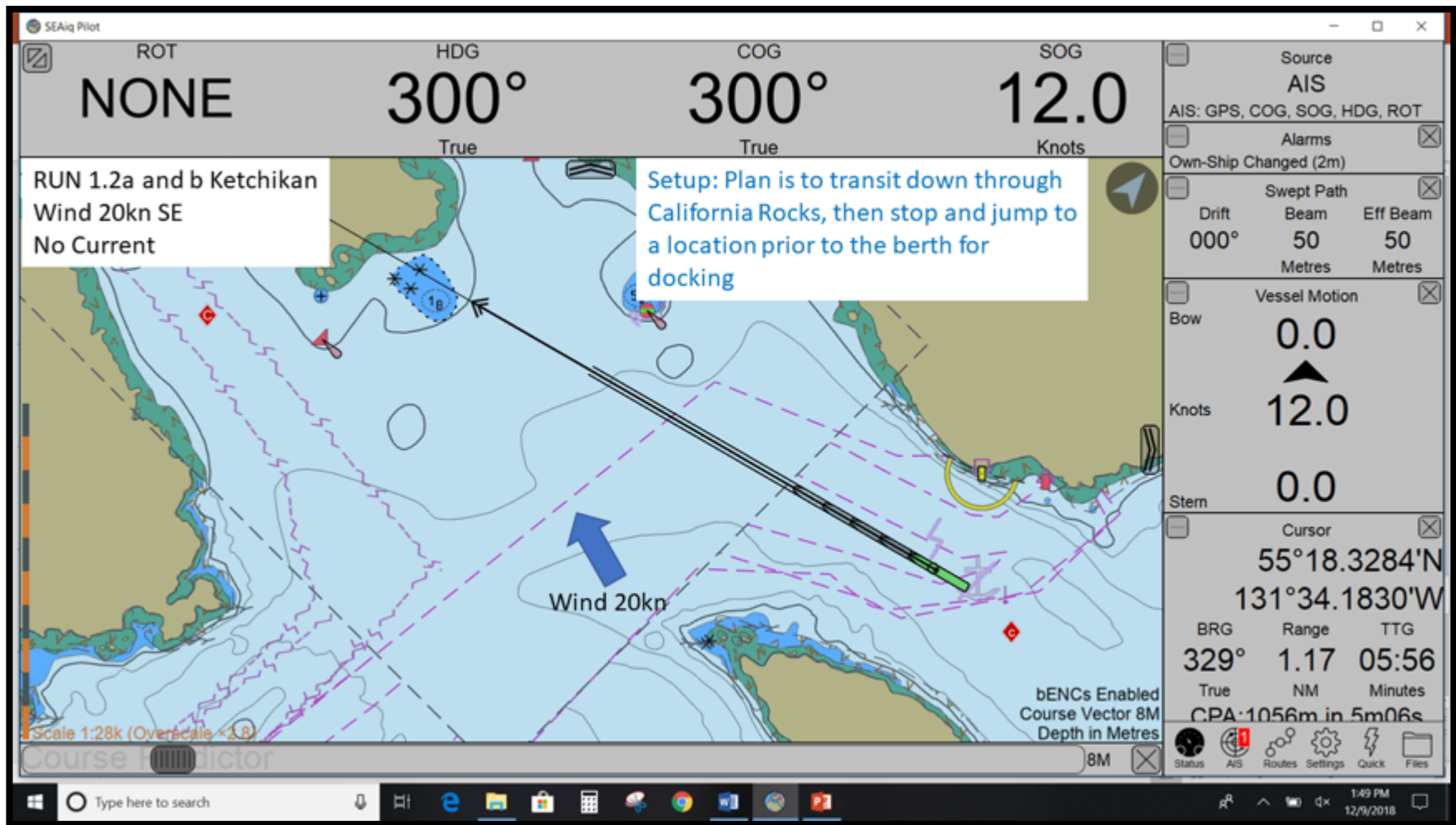


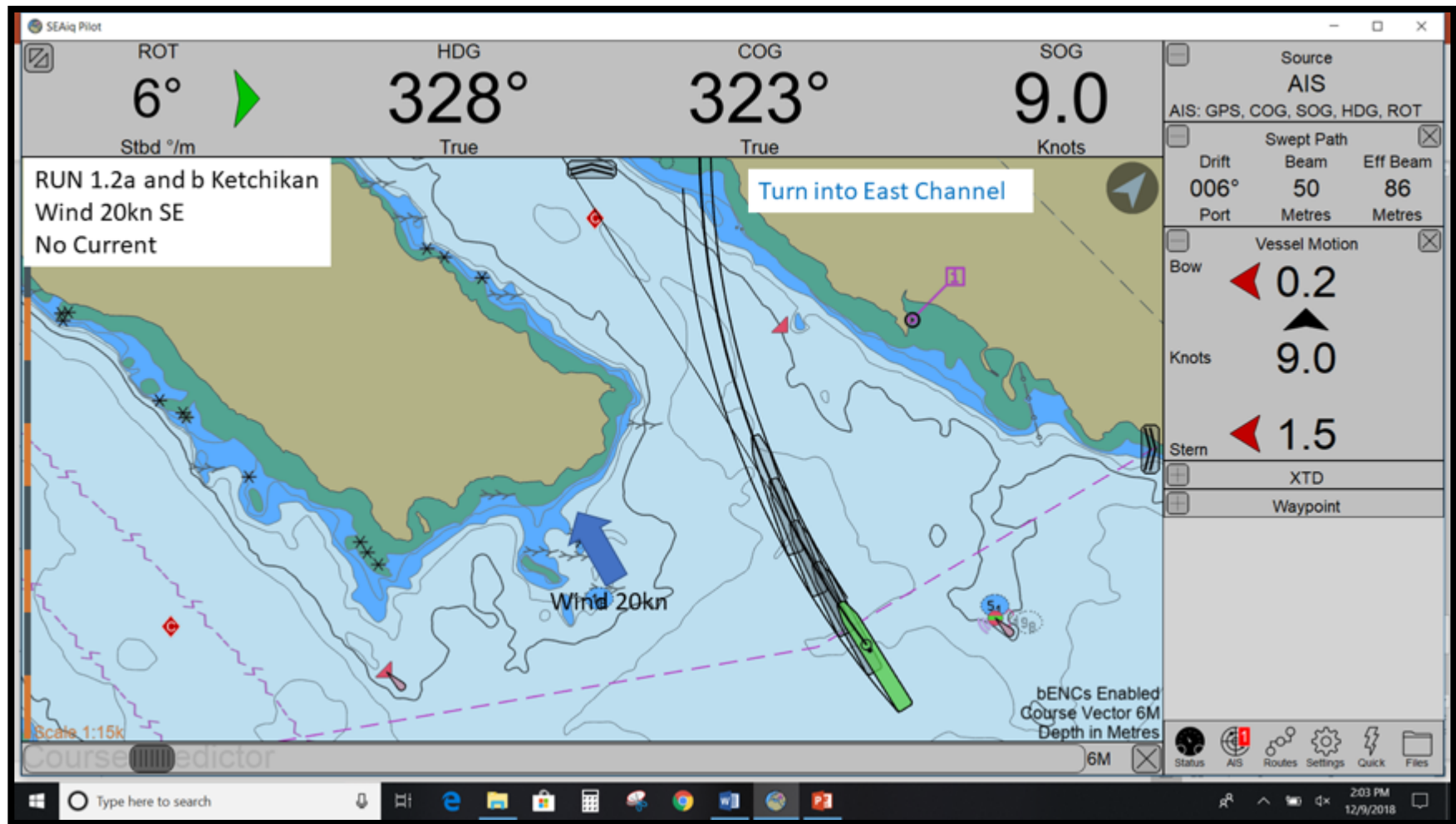
Run 1.2 A-B Ketchikan IB

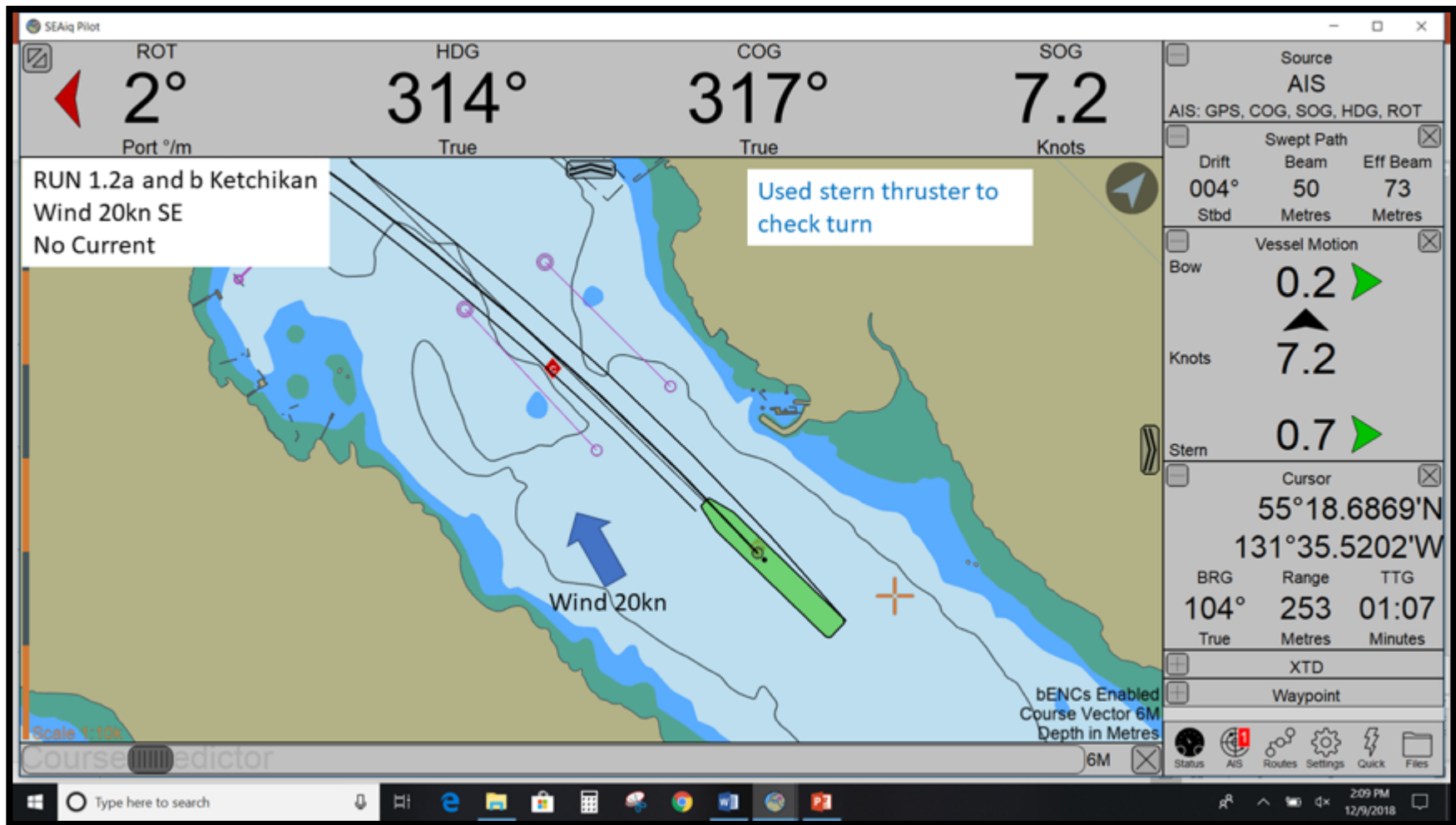
1.2a and b, Ketchikan IB, Docking

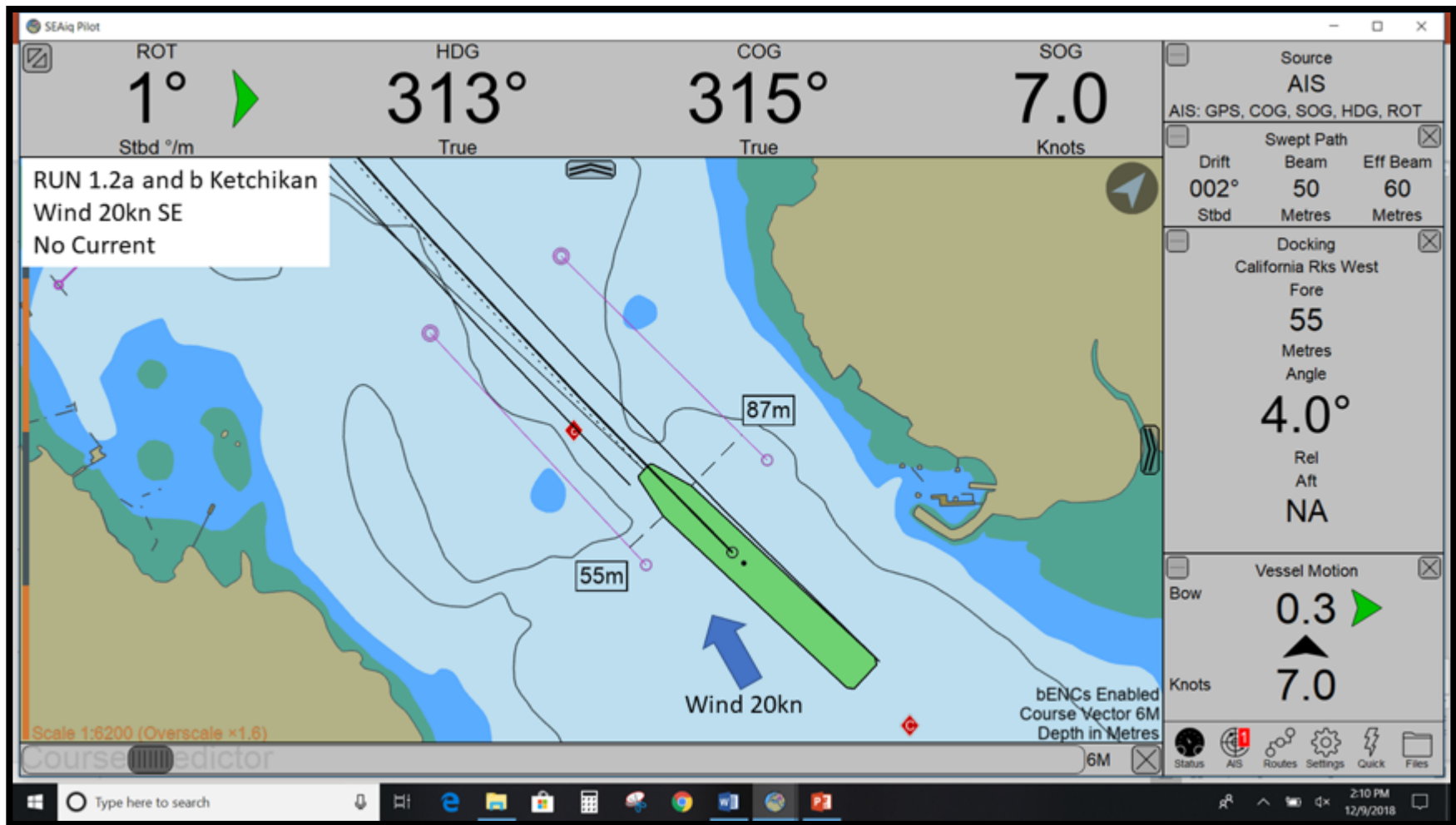
Sunday 12/9/2018

4th run

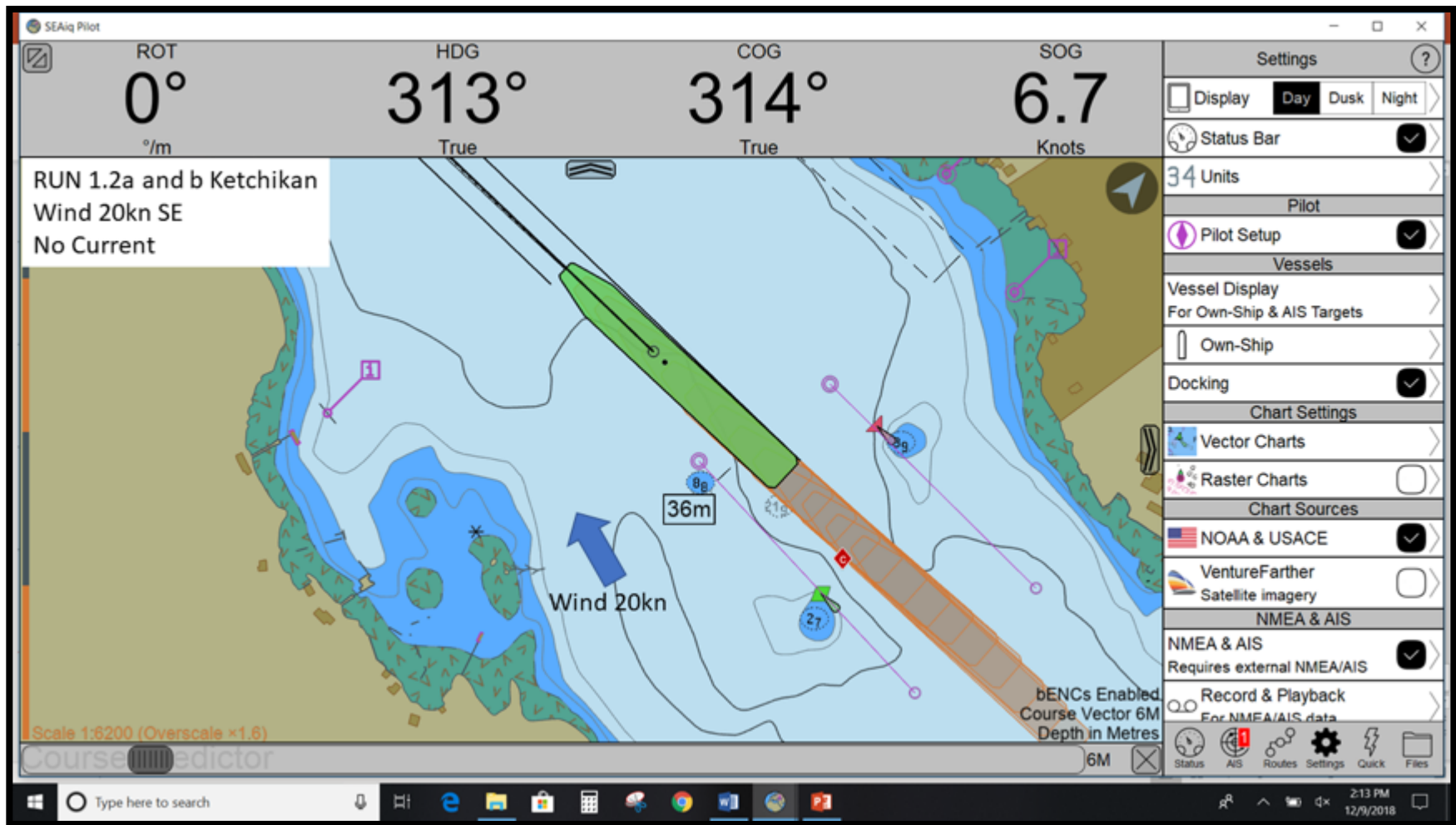


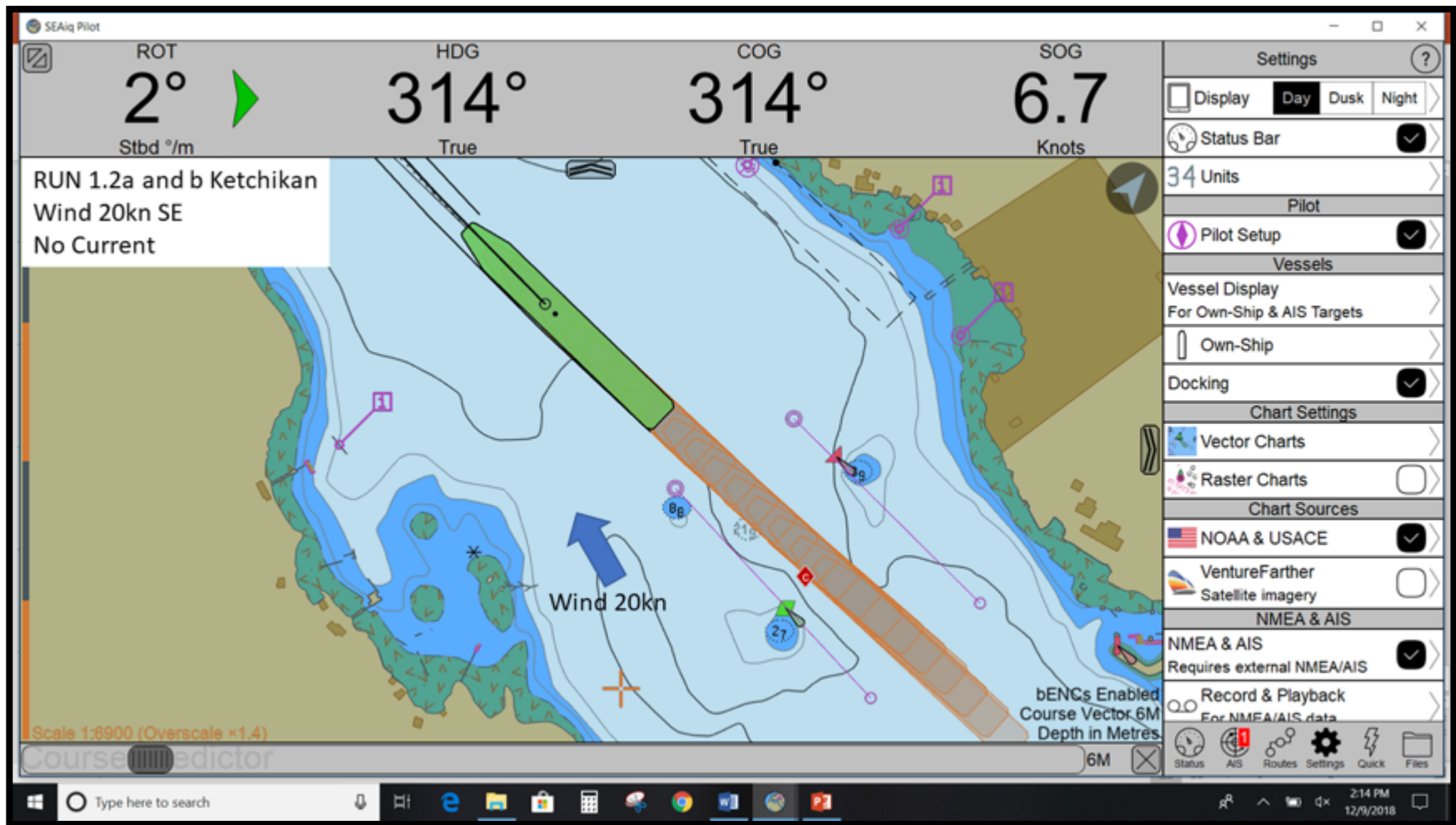










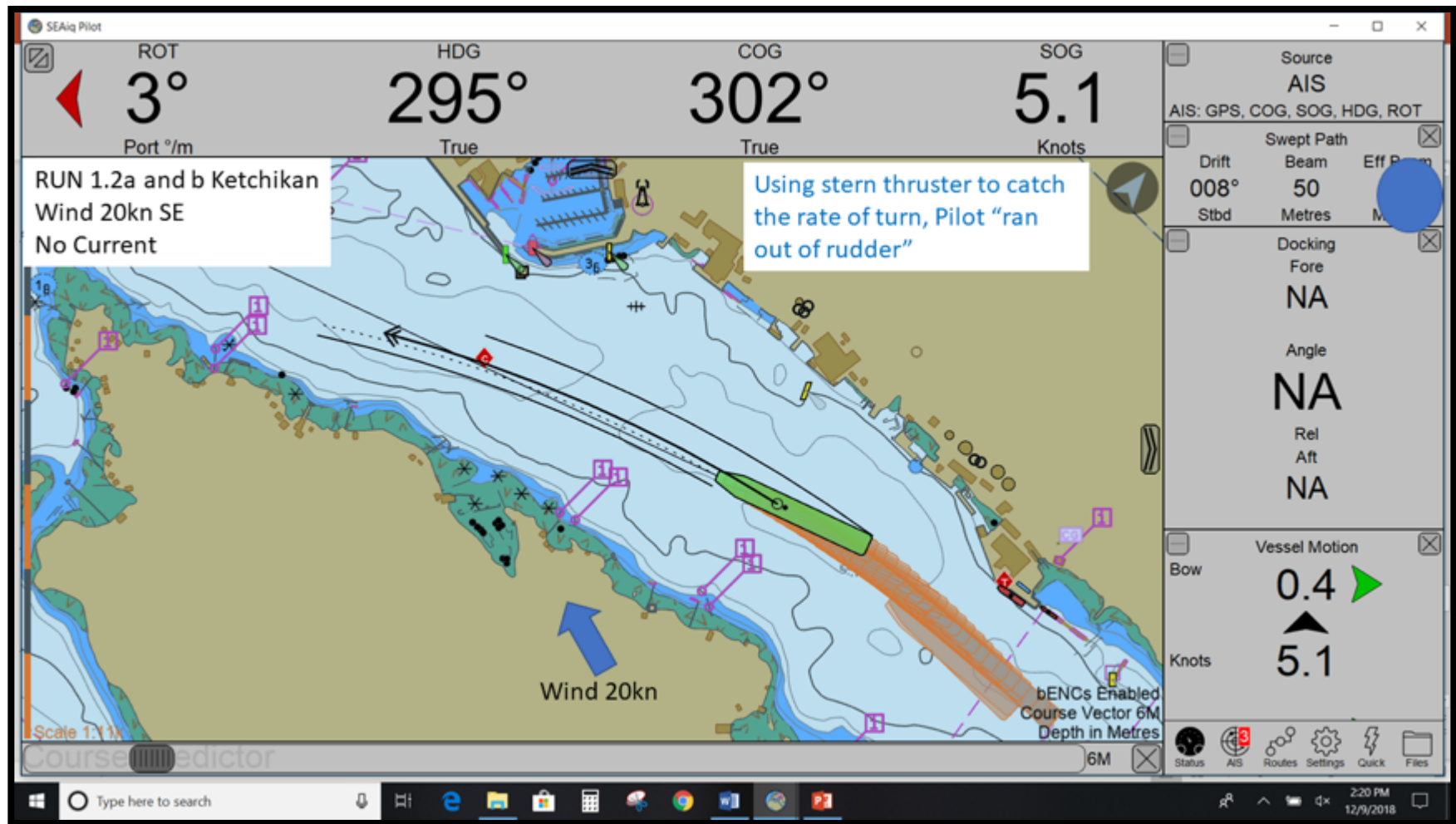


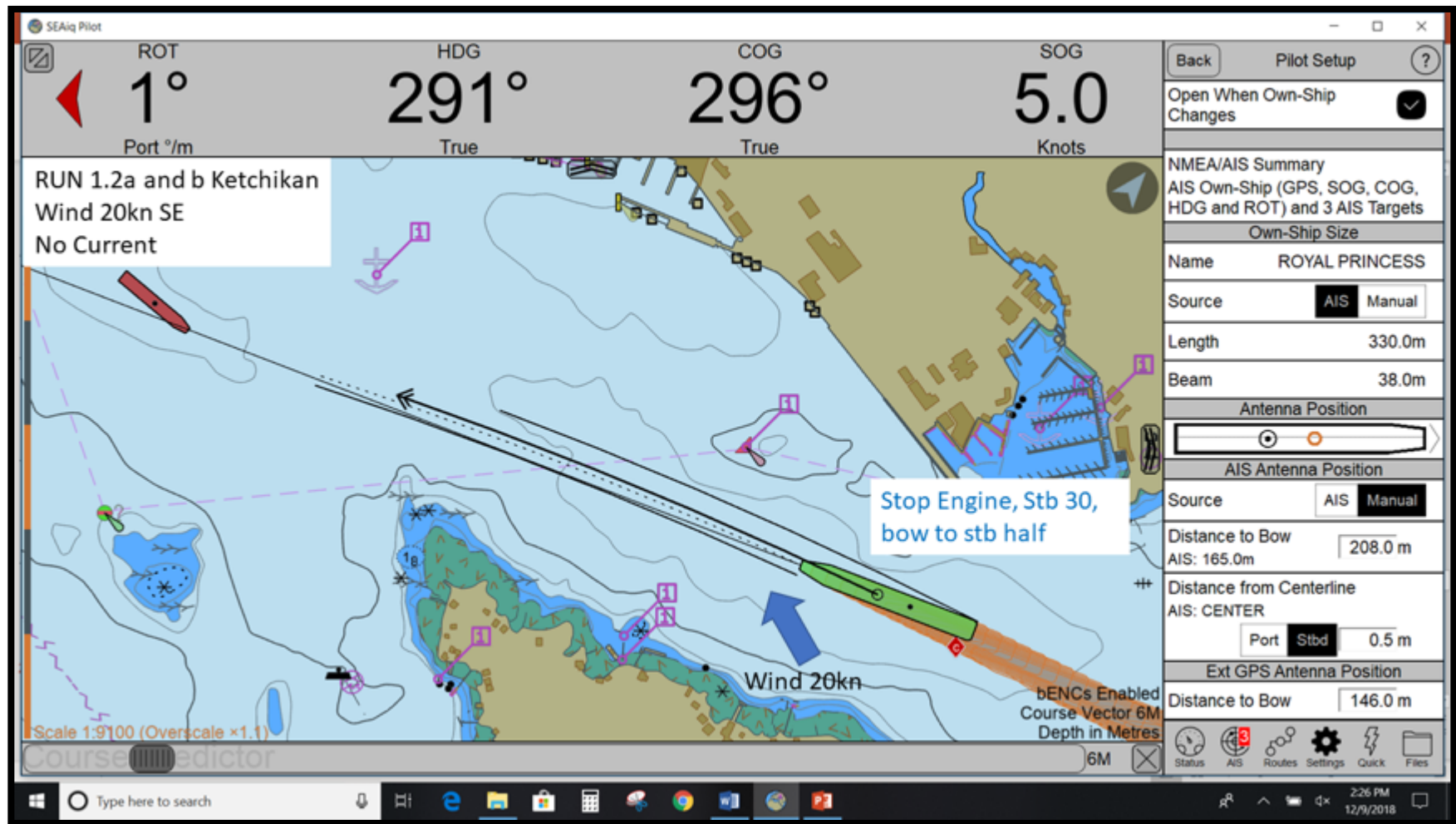
Run 1.2 A-B Ketchikan IB Part B

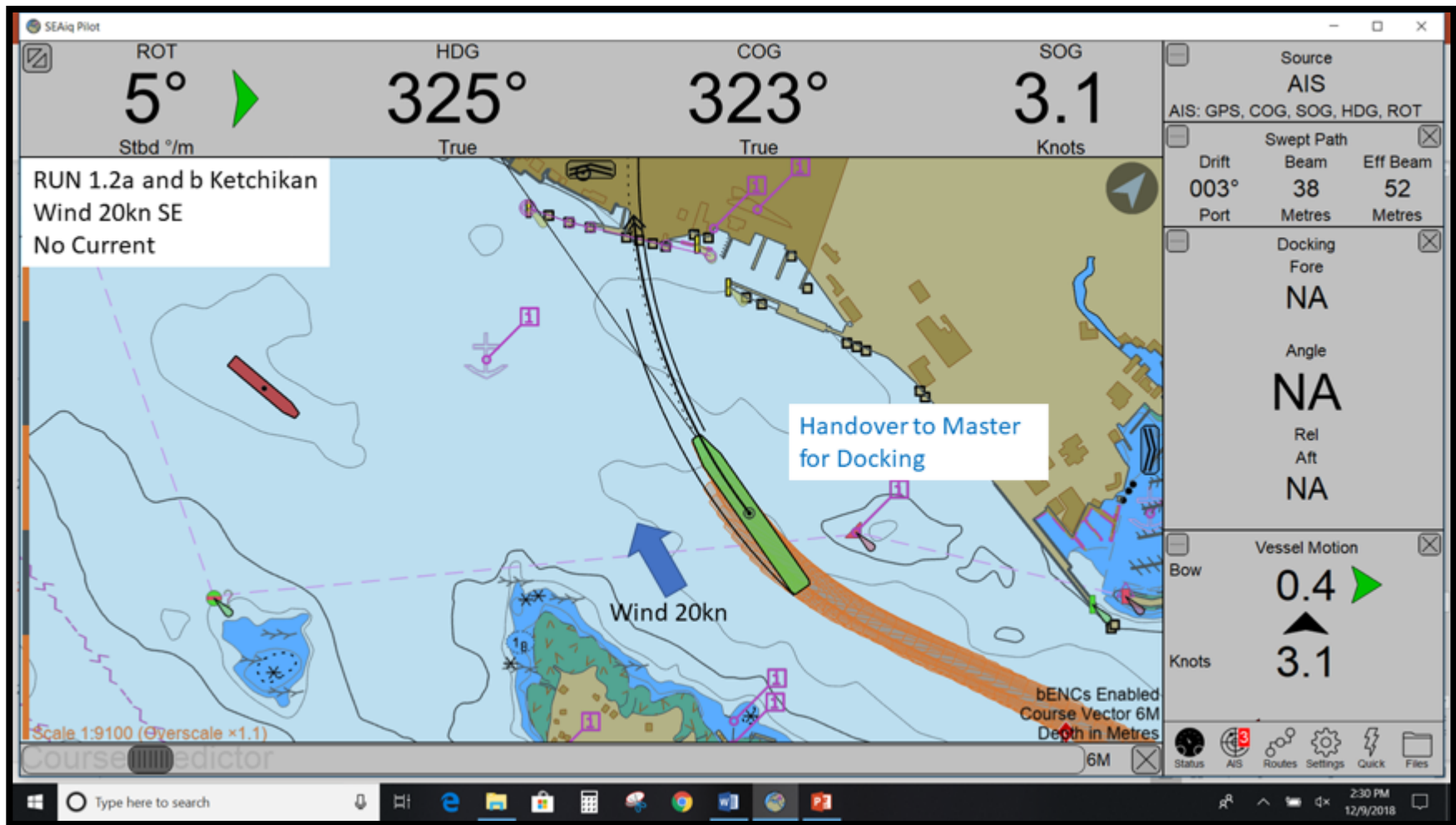
1.2b, Jump from CA Rocks to Dock Area

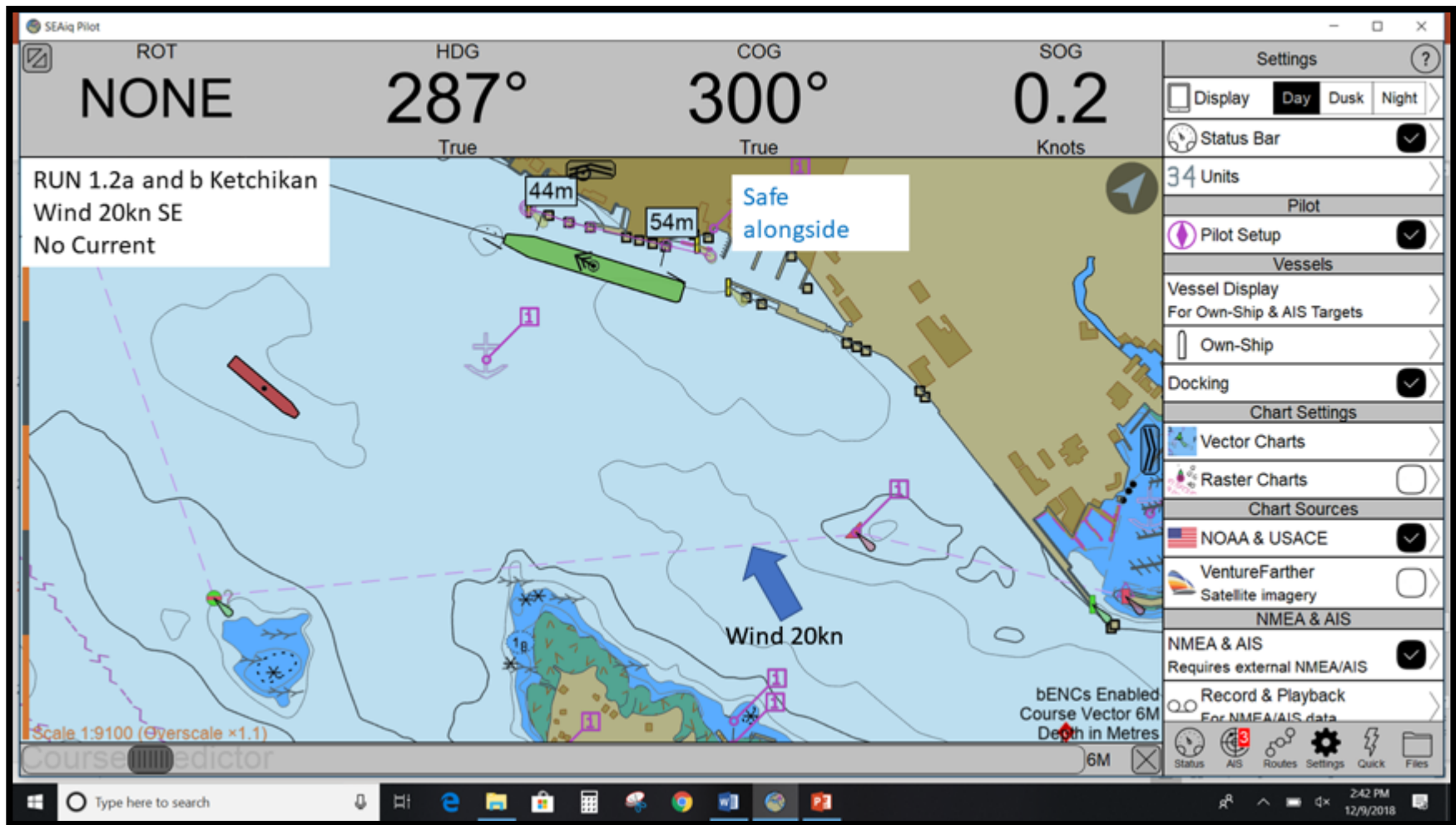
Sunday 12/9/2018

5th run







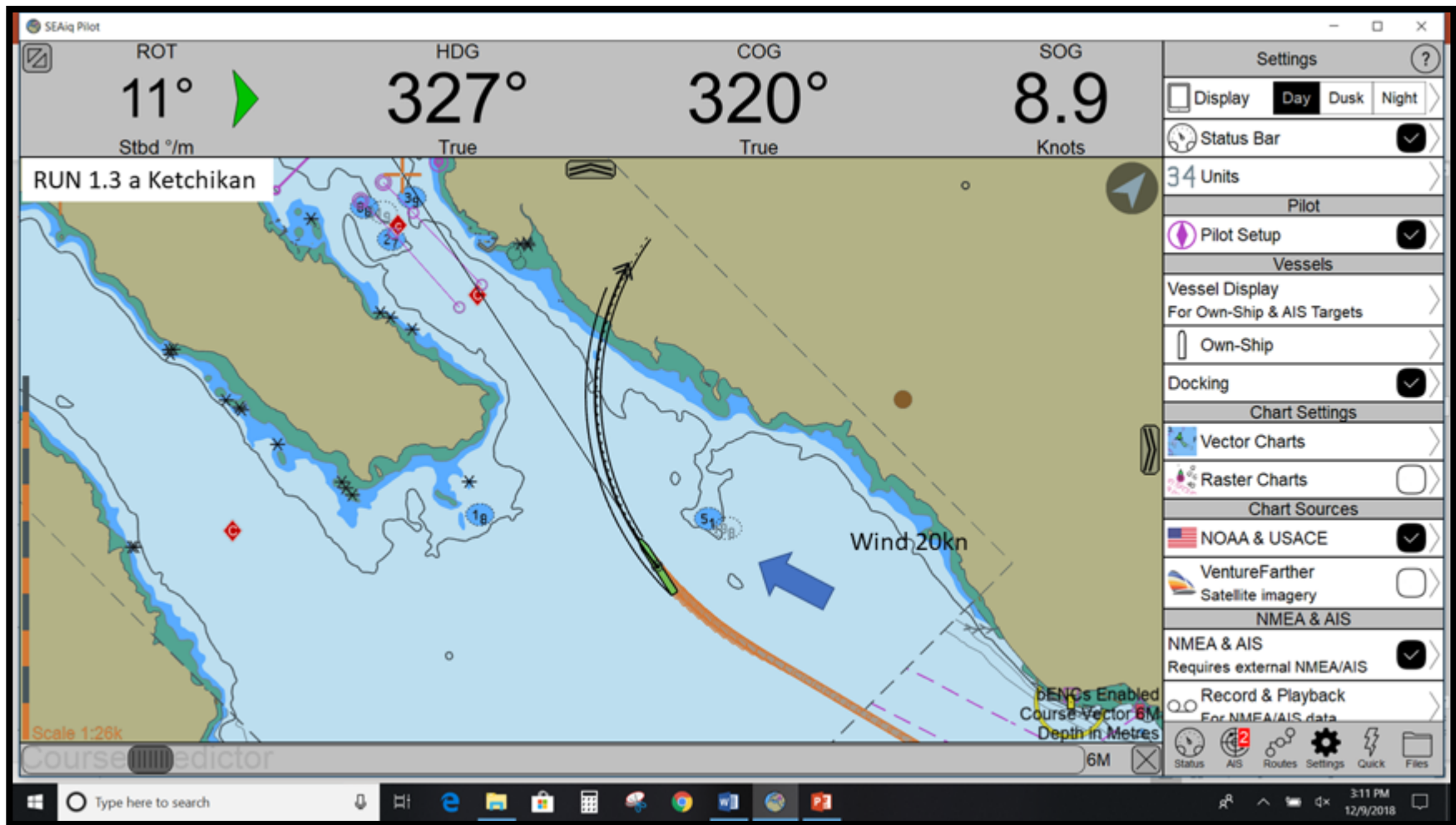


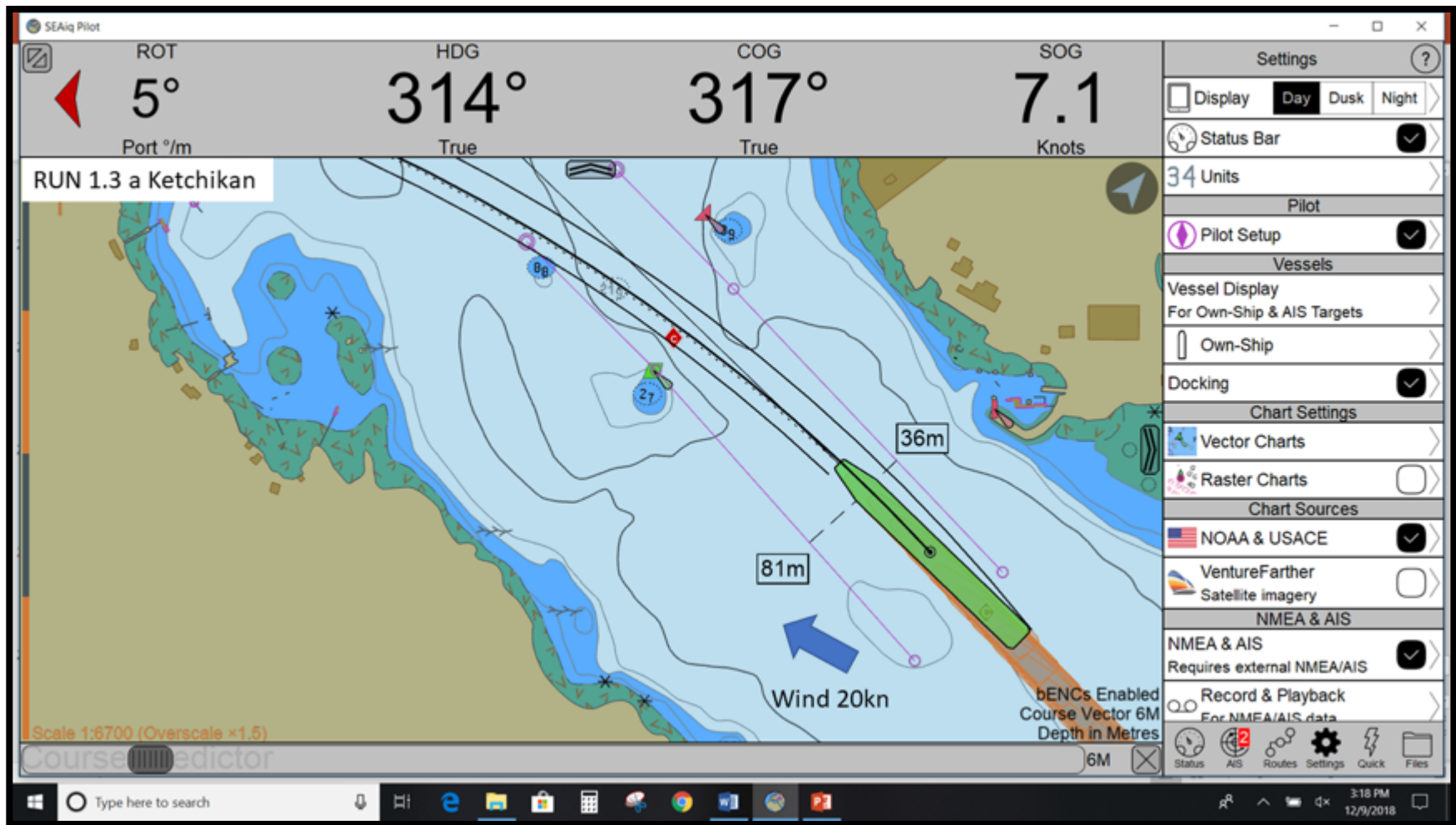
Run 1.3 SE 25 Ketchikan IB

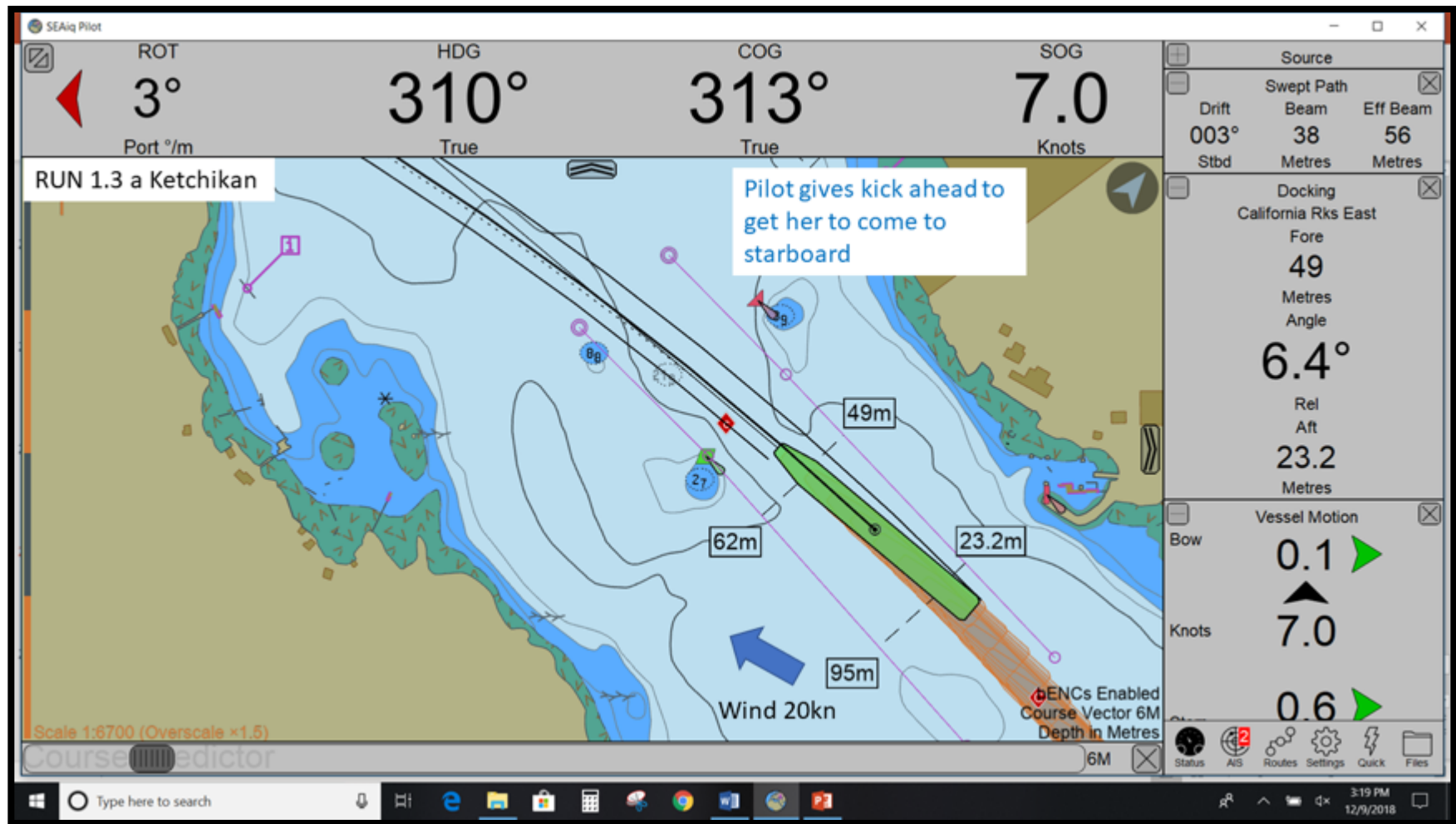
1.3 SE 25 No Current, Ketchikan

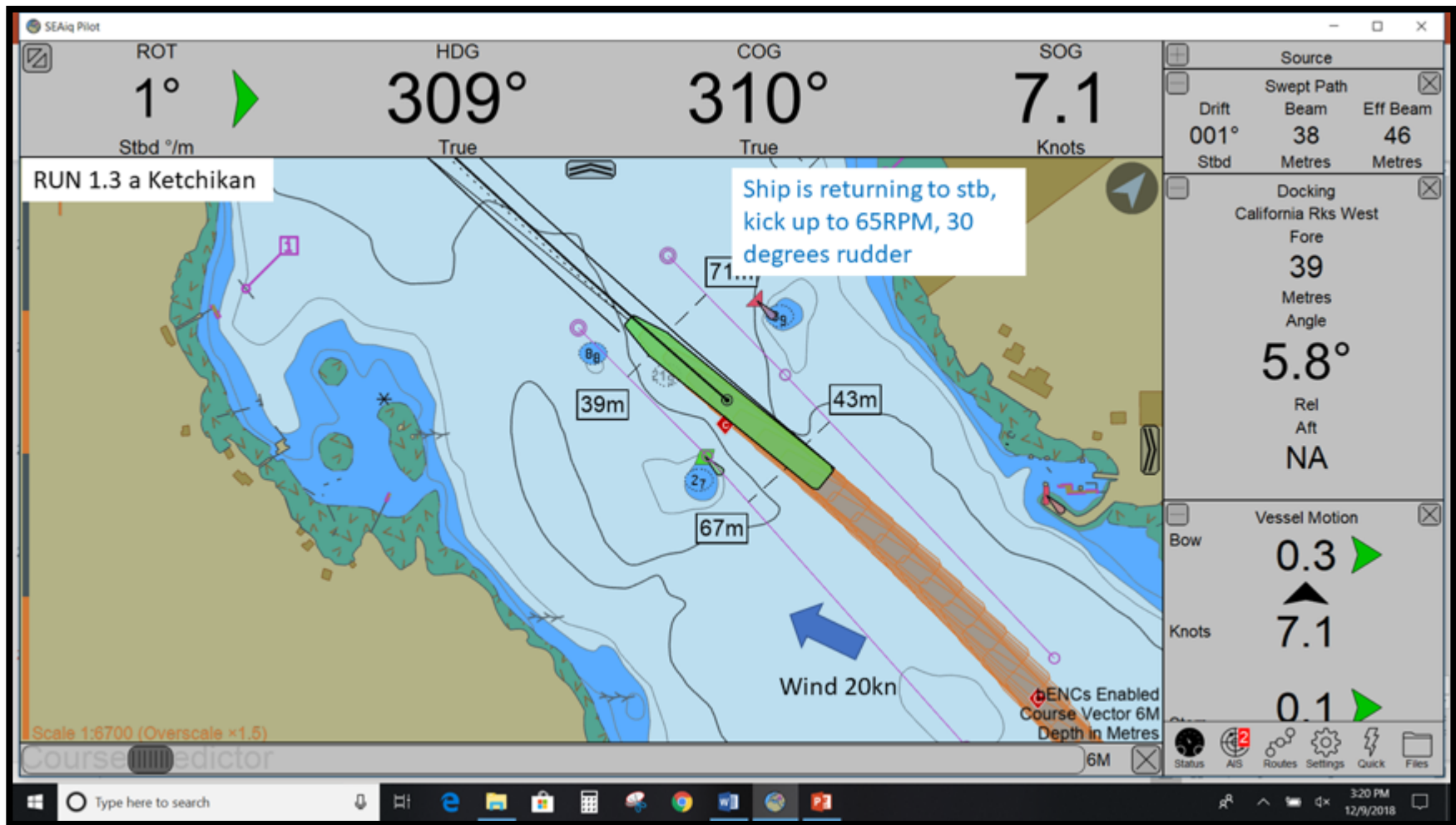
Sunday 12/9/2018

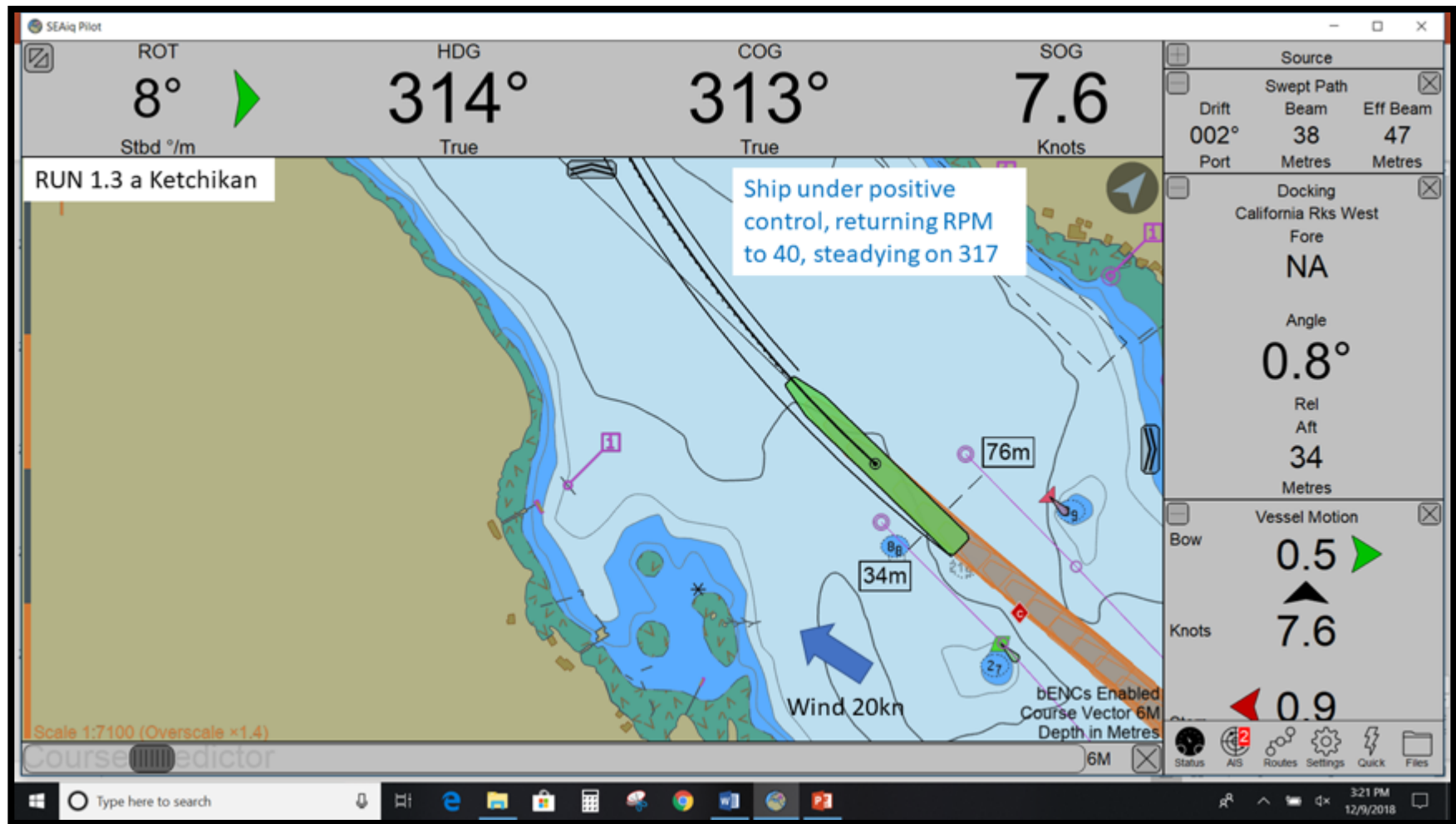
6th Run

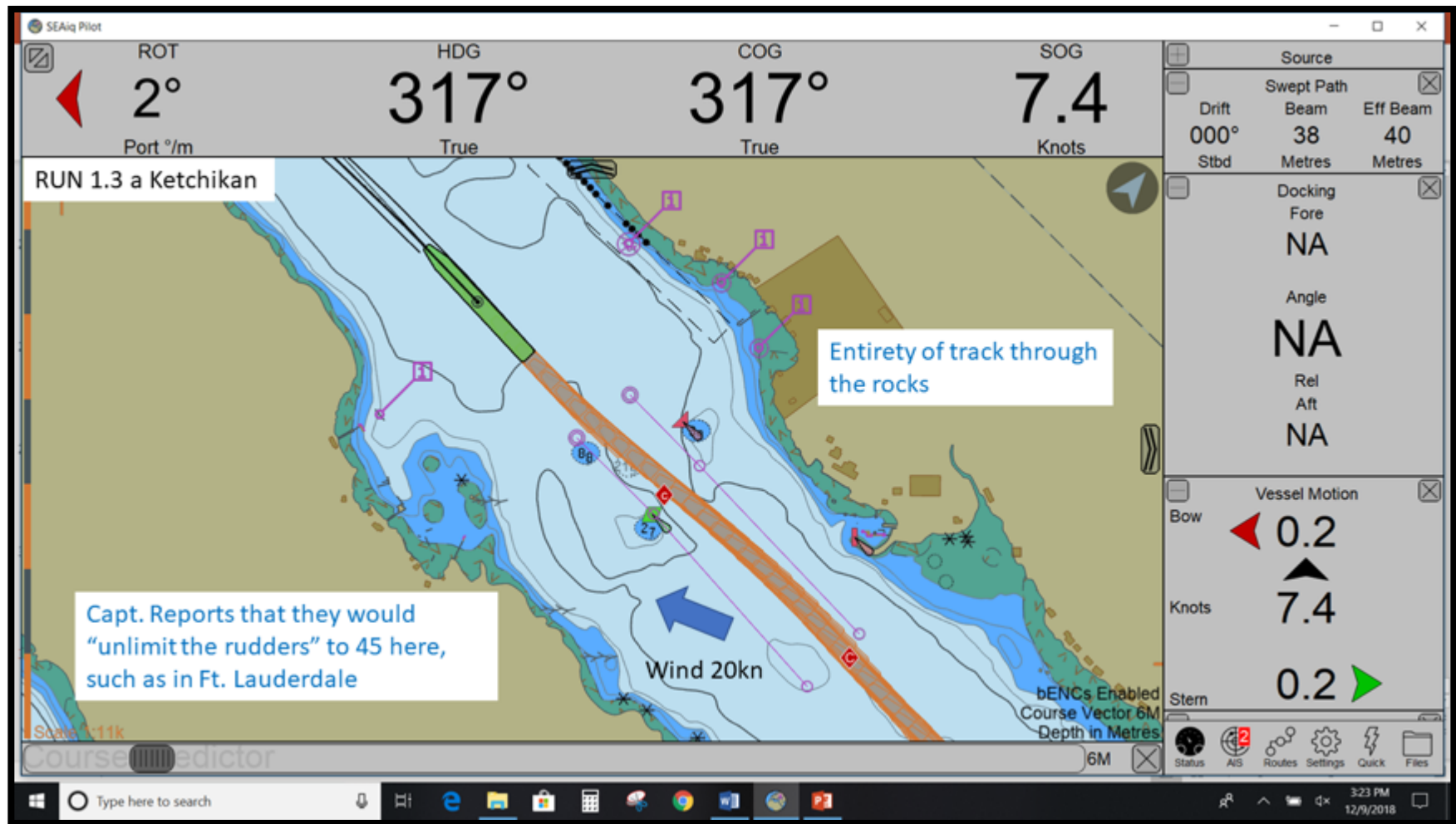










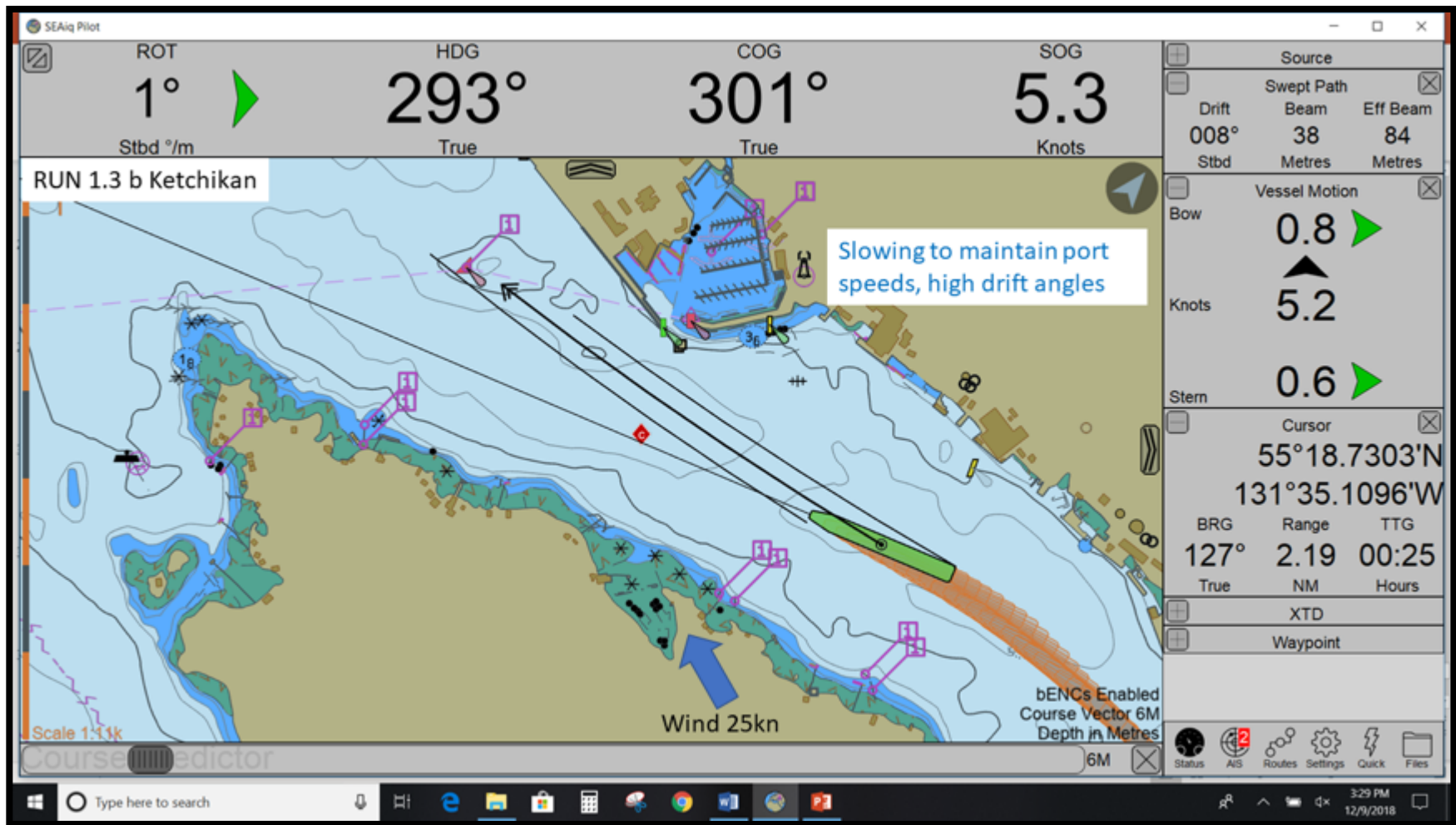


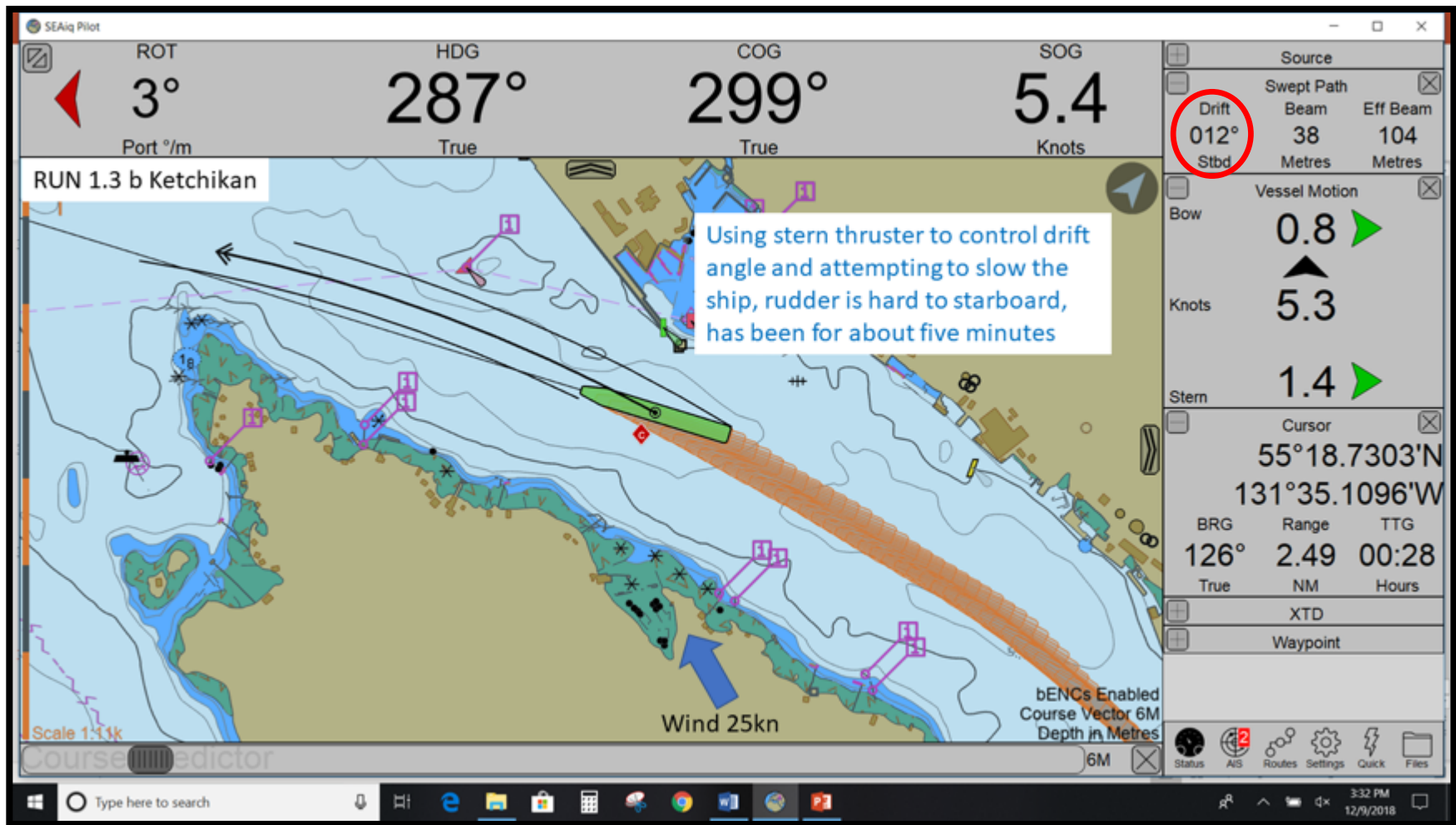
Run 1.3B, Ketchikan IB, 20kn SSE

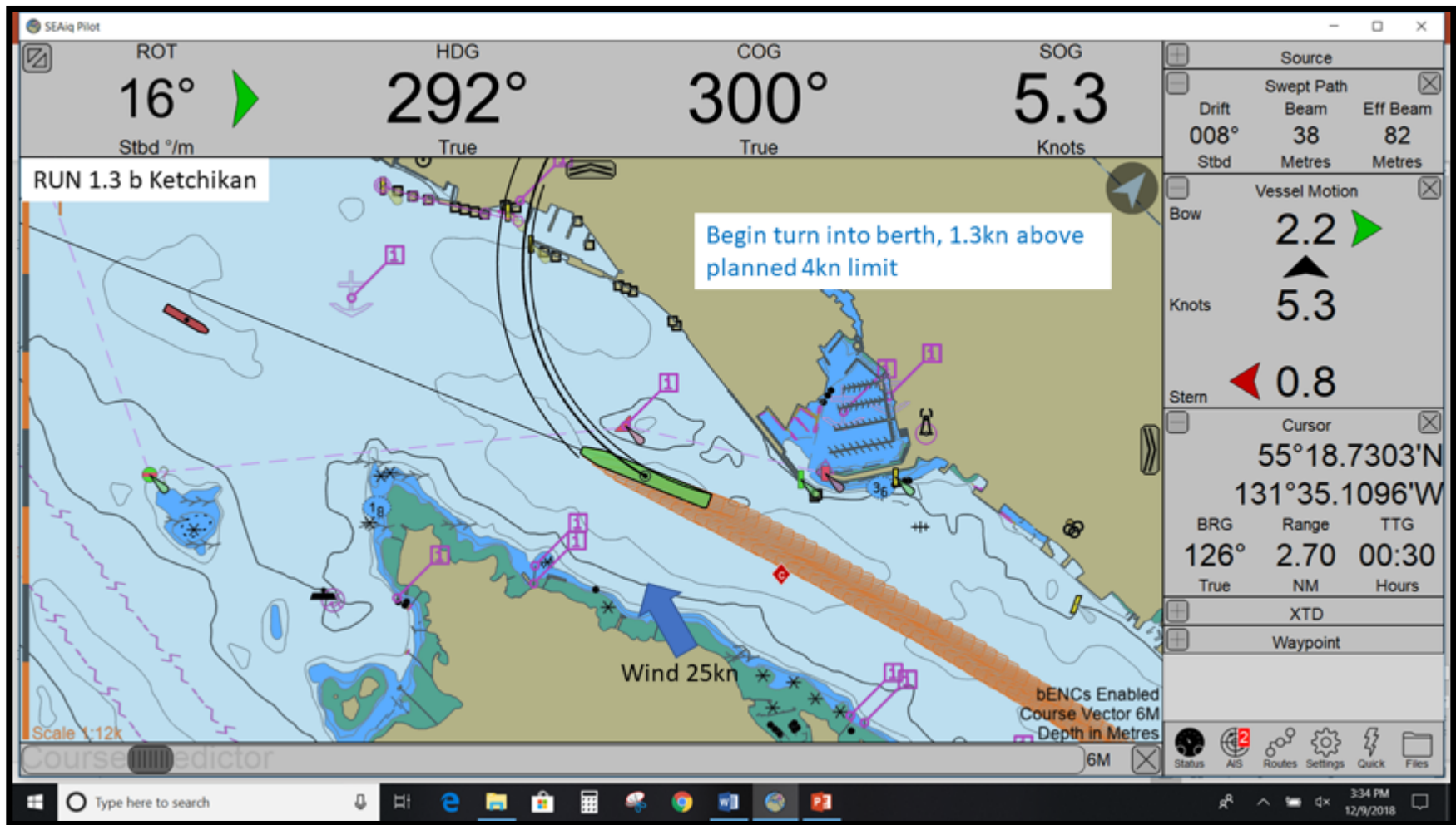
1.3b, Jump from CA Rocks to Dock Area, 20 kn SSE

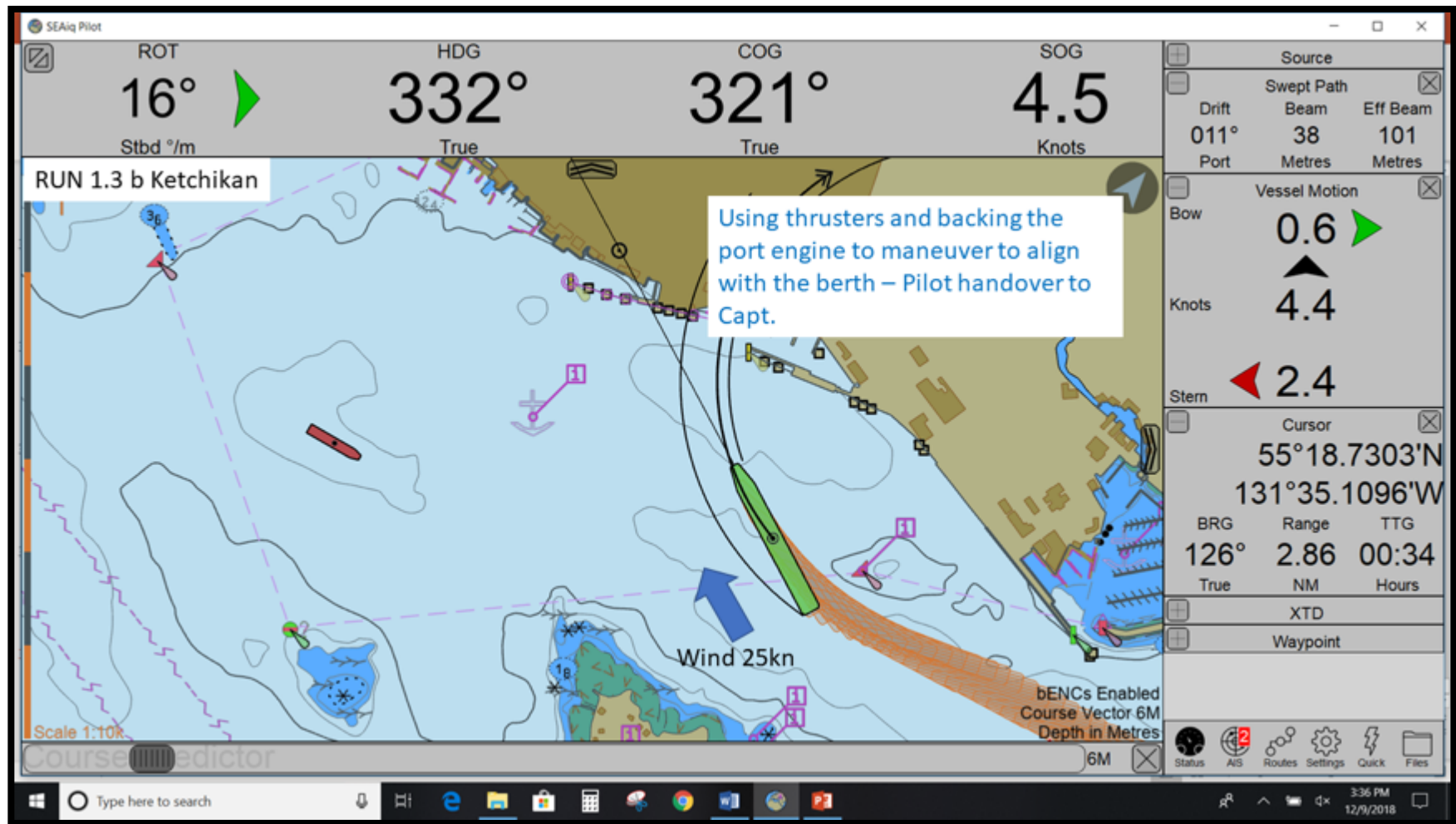
Sunday 12/9/2018

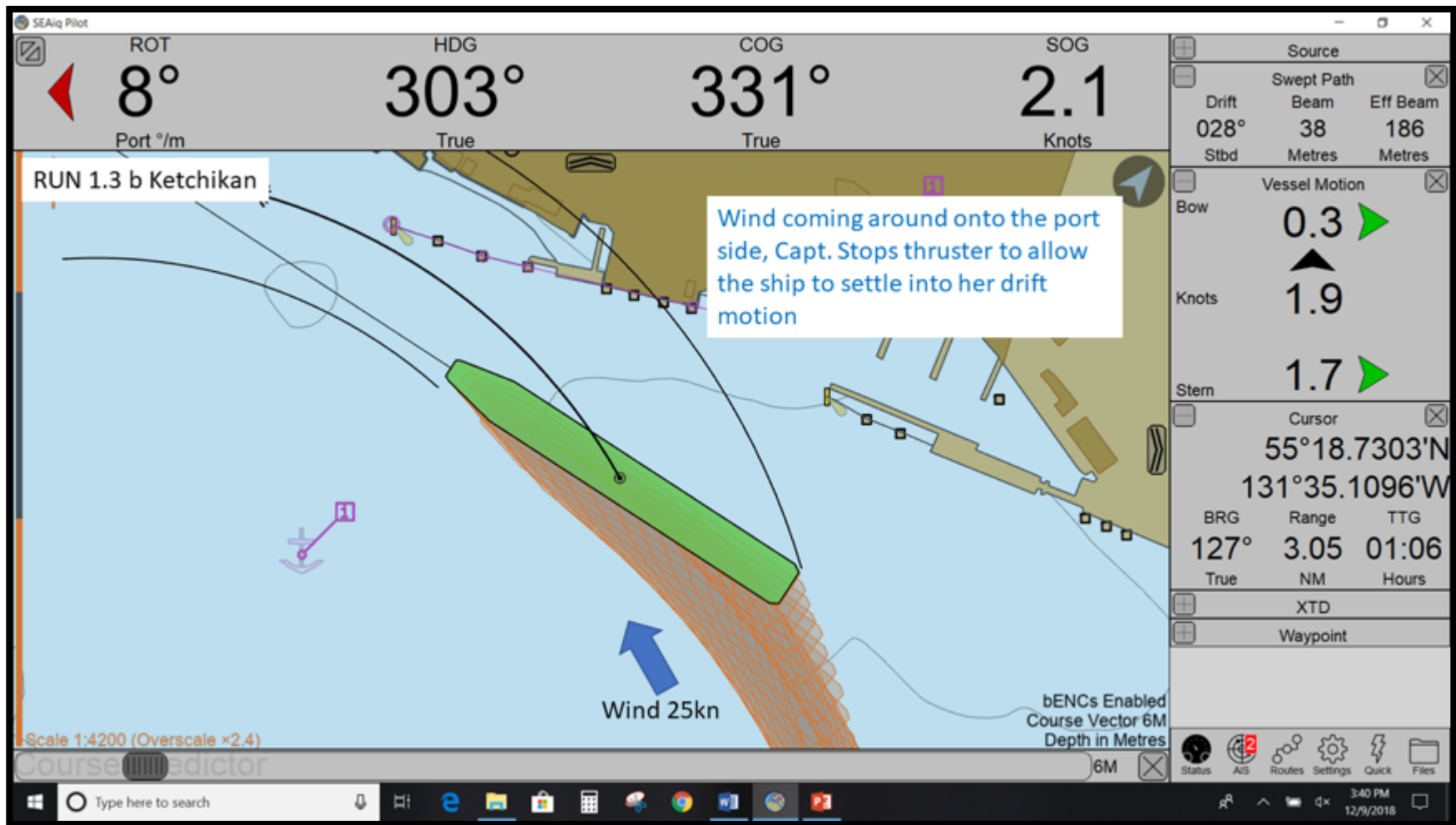
7th run

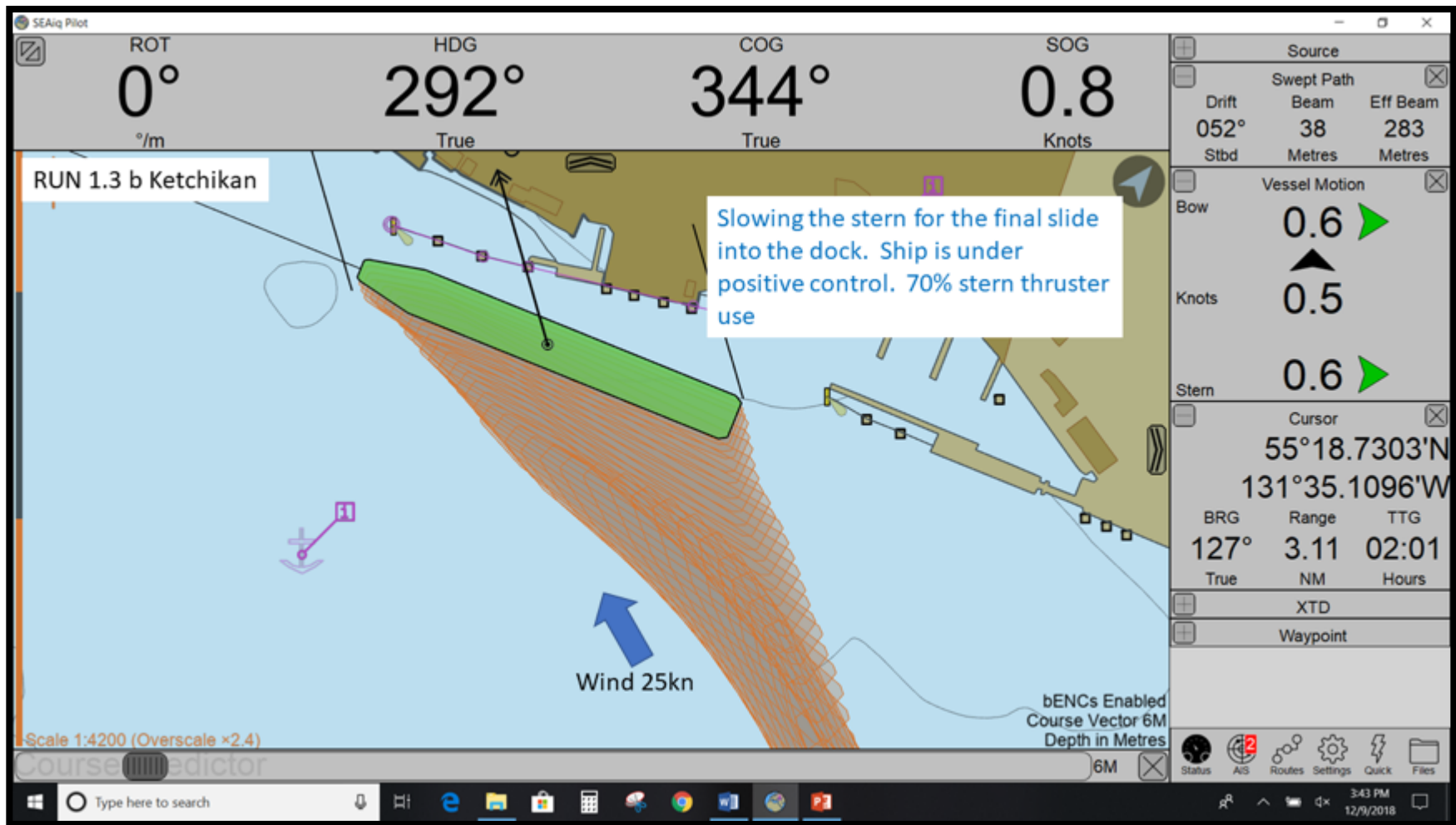










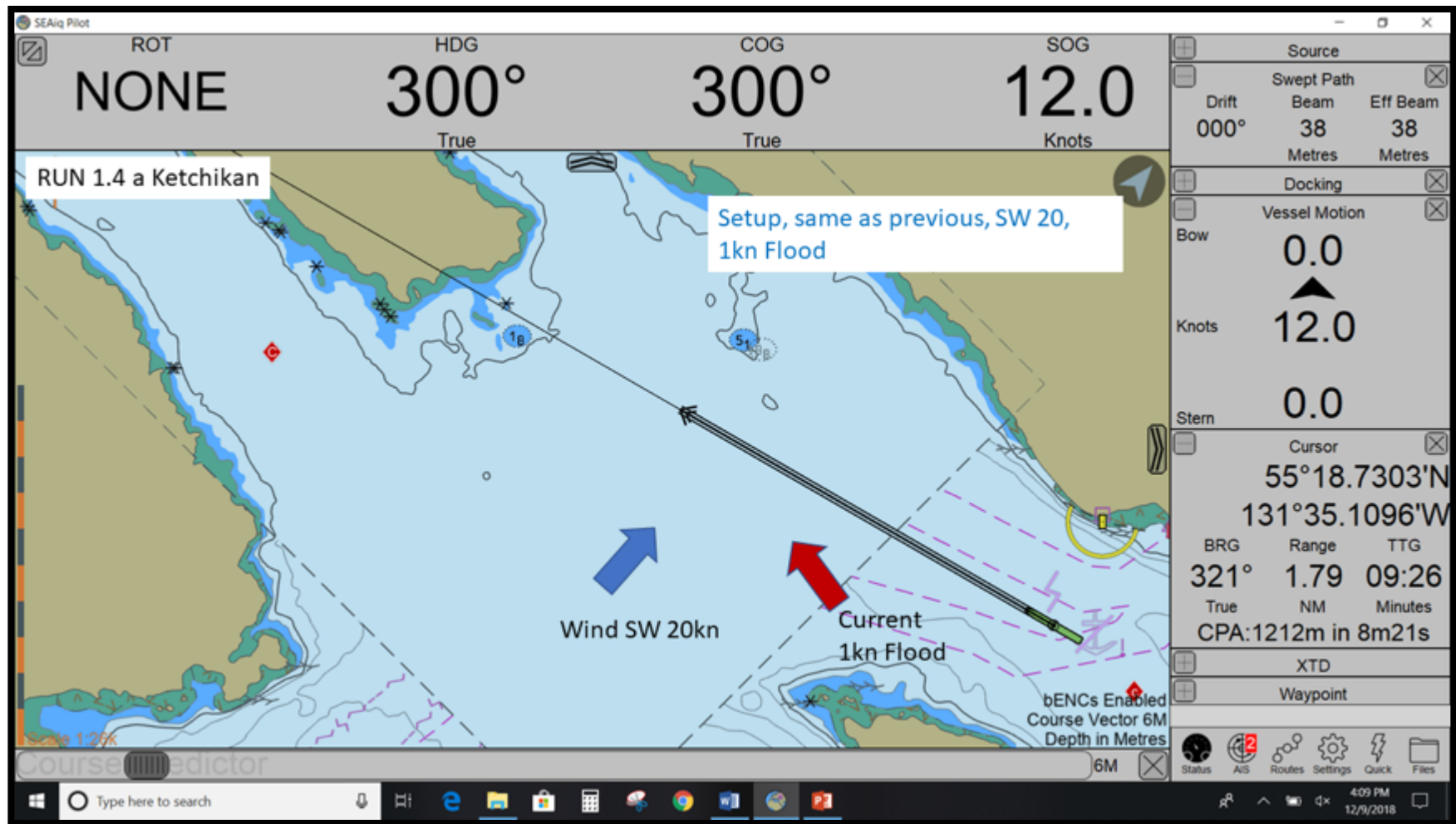


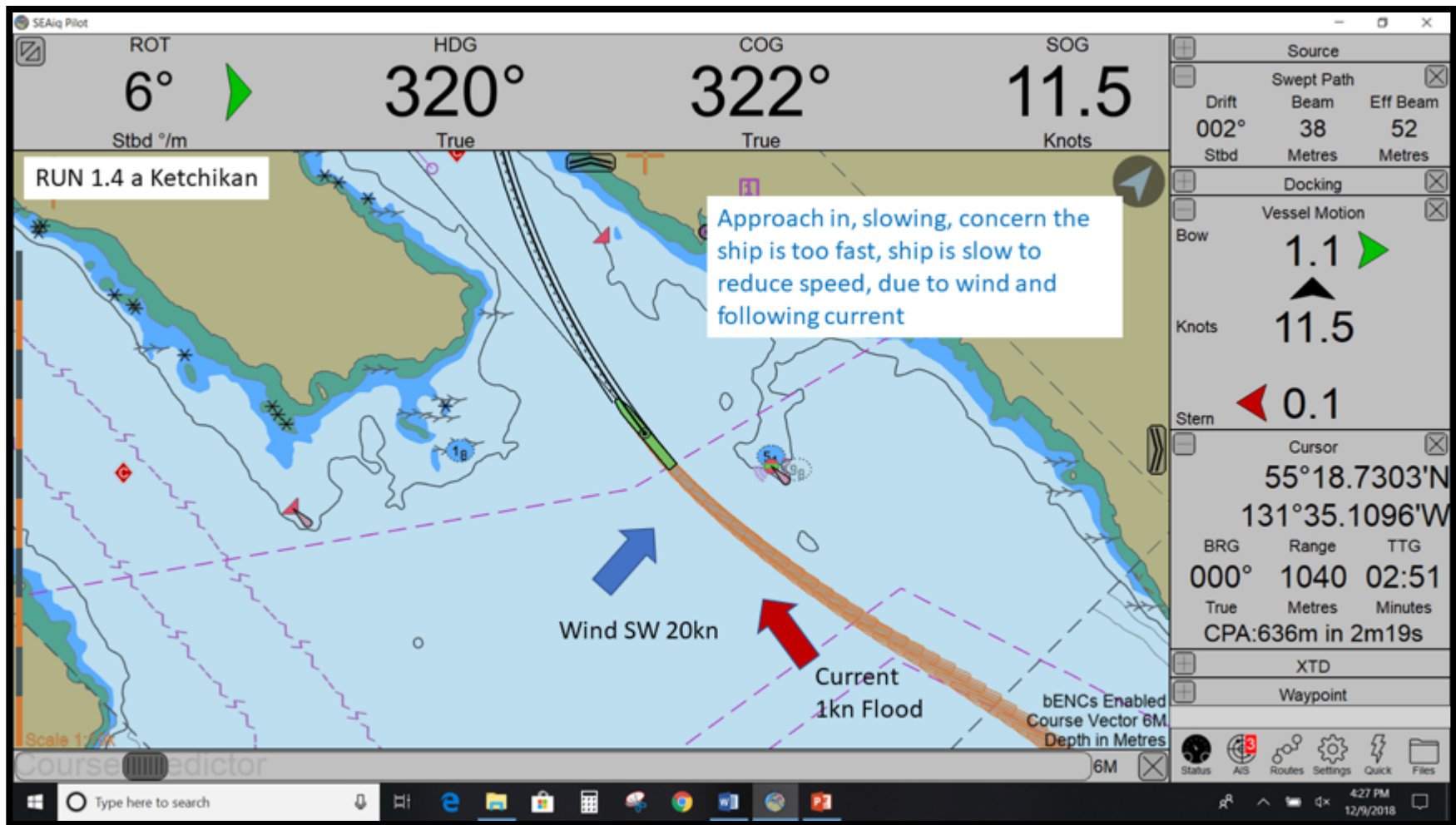
Run 1.4 A-B Ketchikan, SW20 1kn Flood

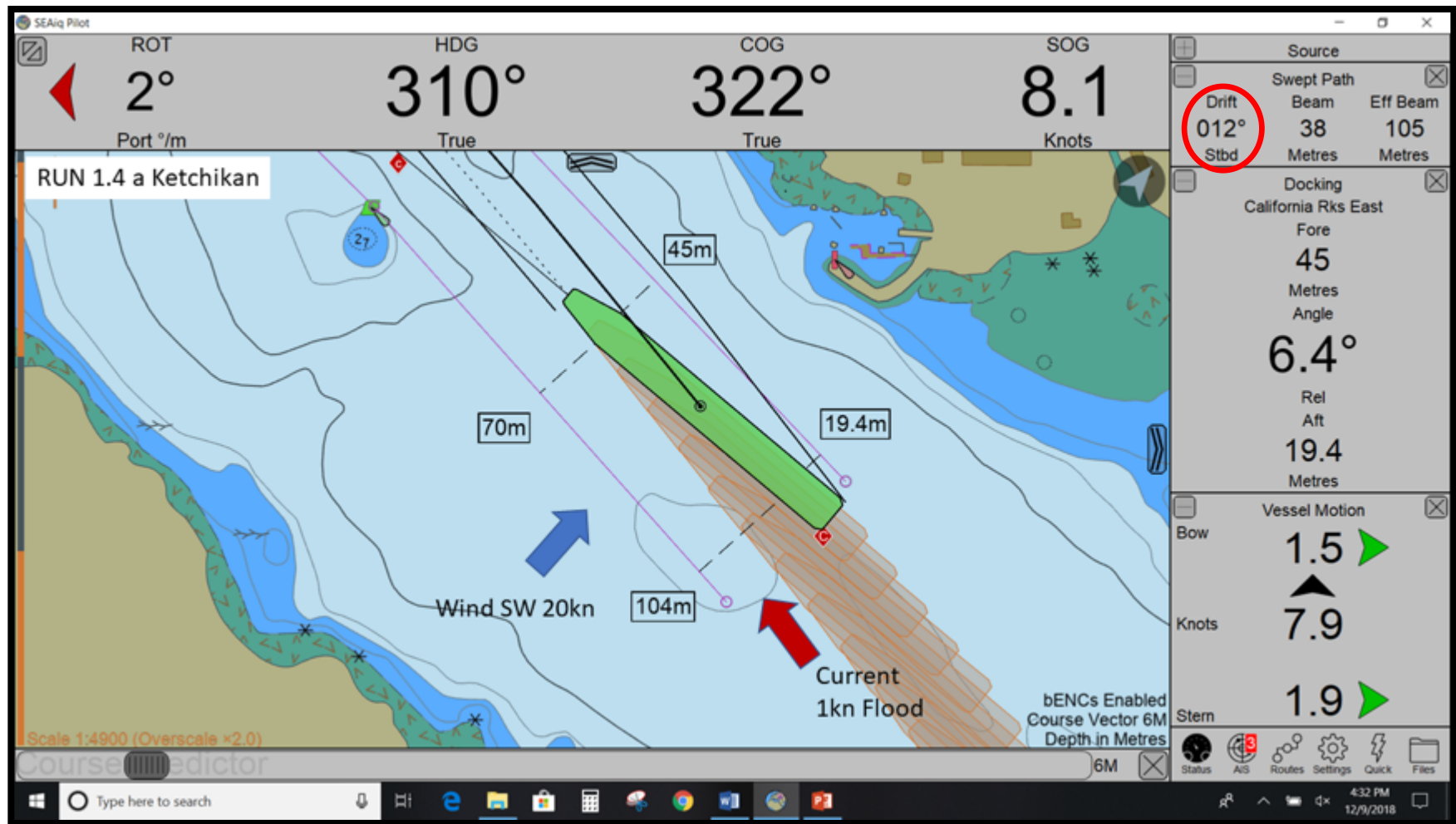
1.4a-b SW 20, 1kn Flood, Ketchikan

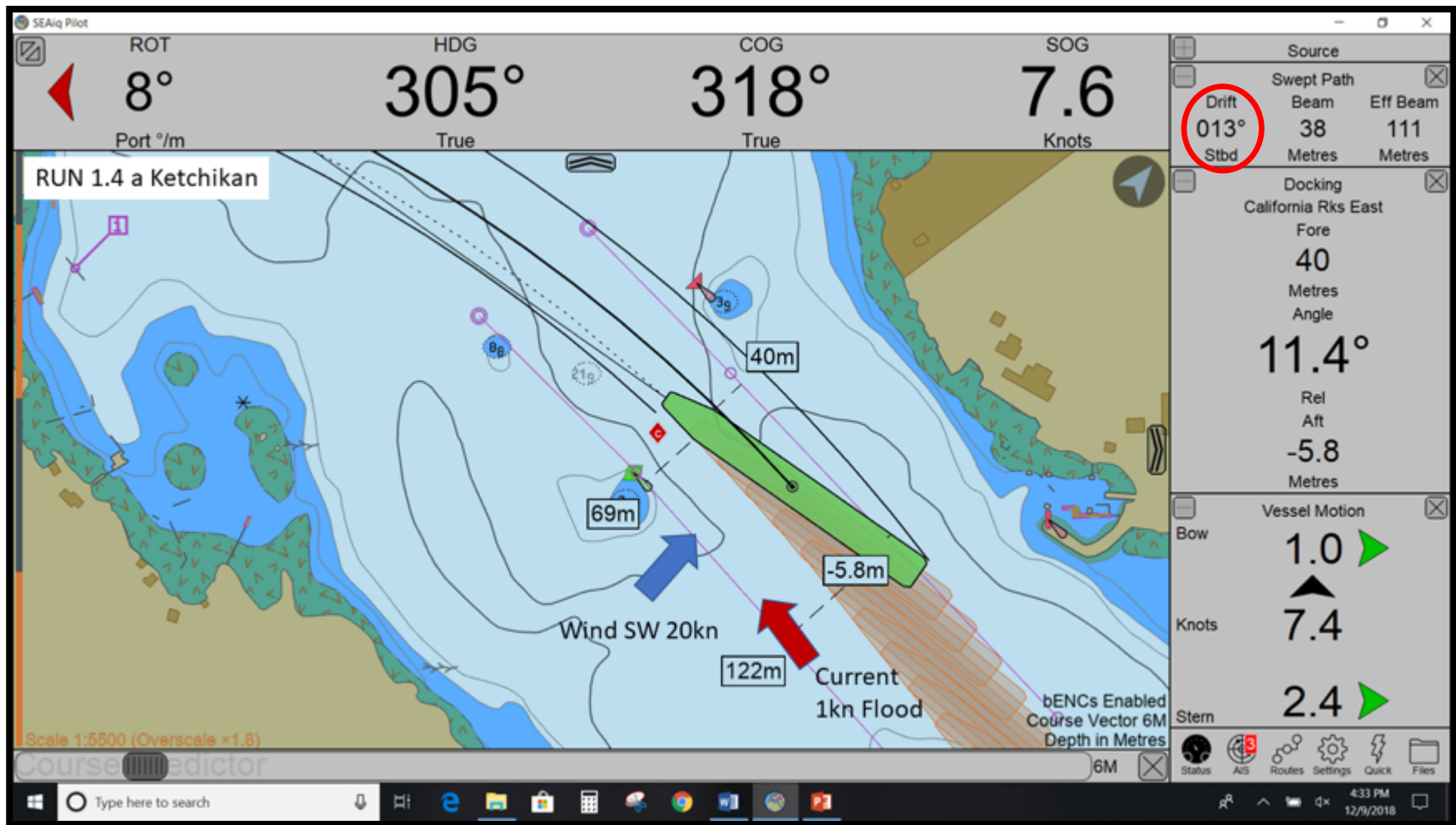
Sunday 12/9/2018

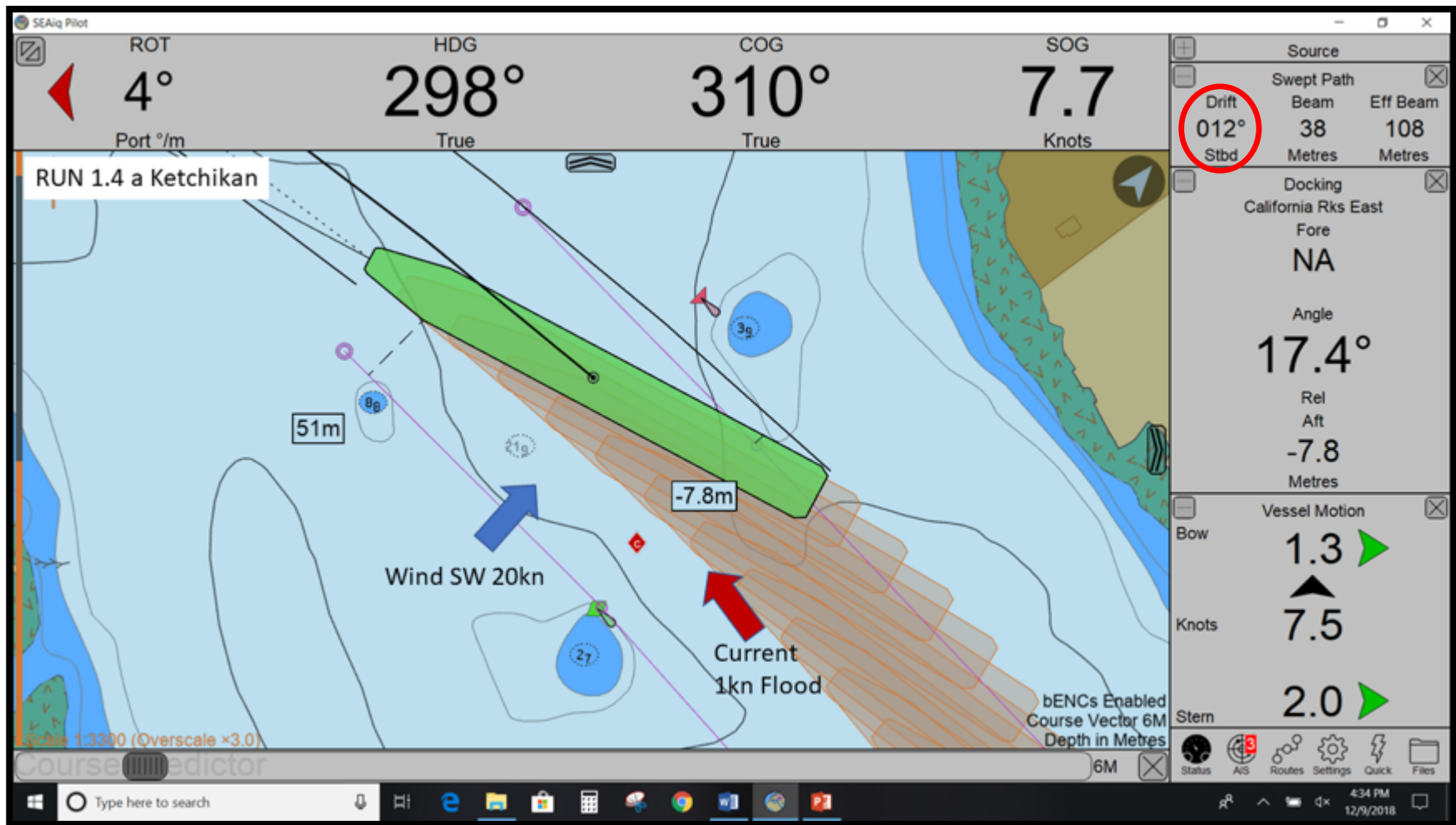
8th Run

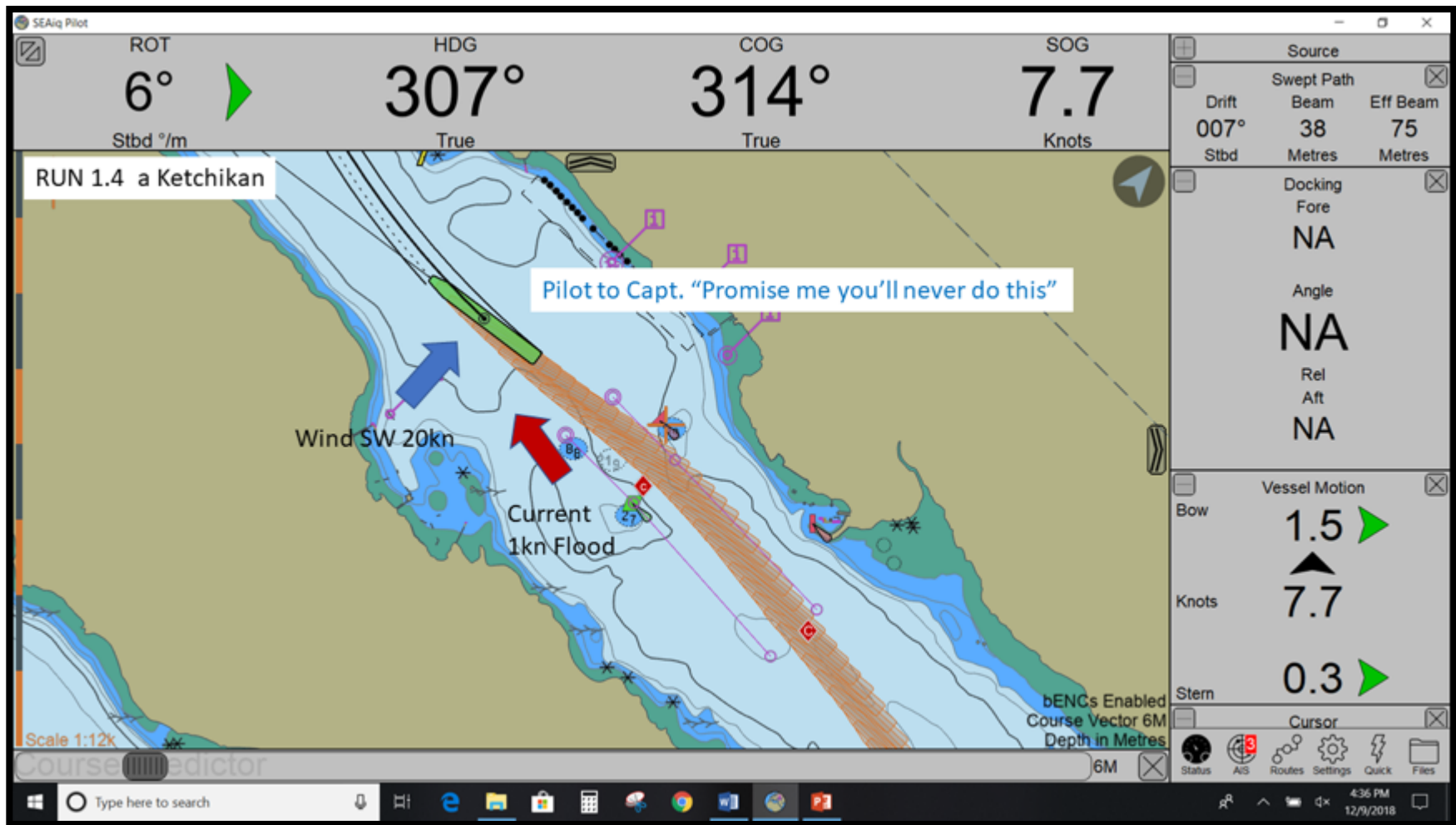










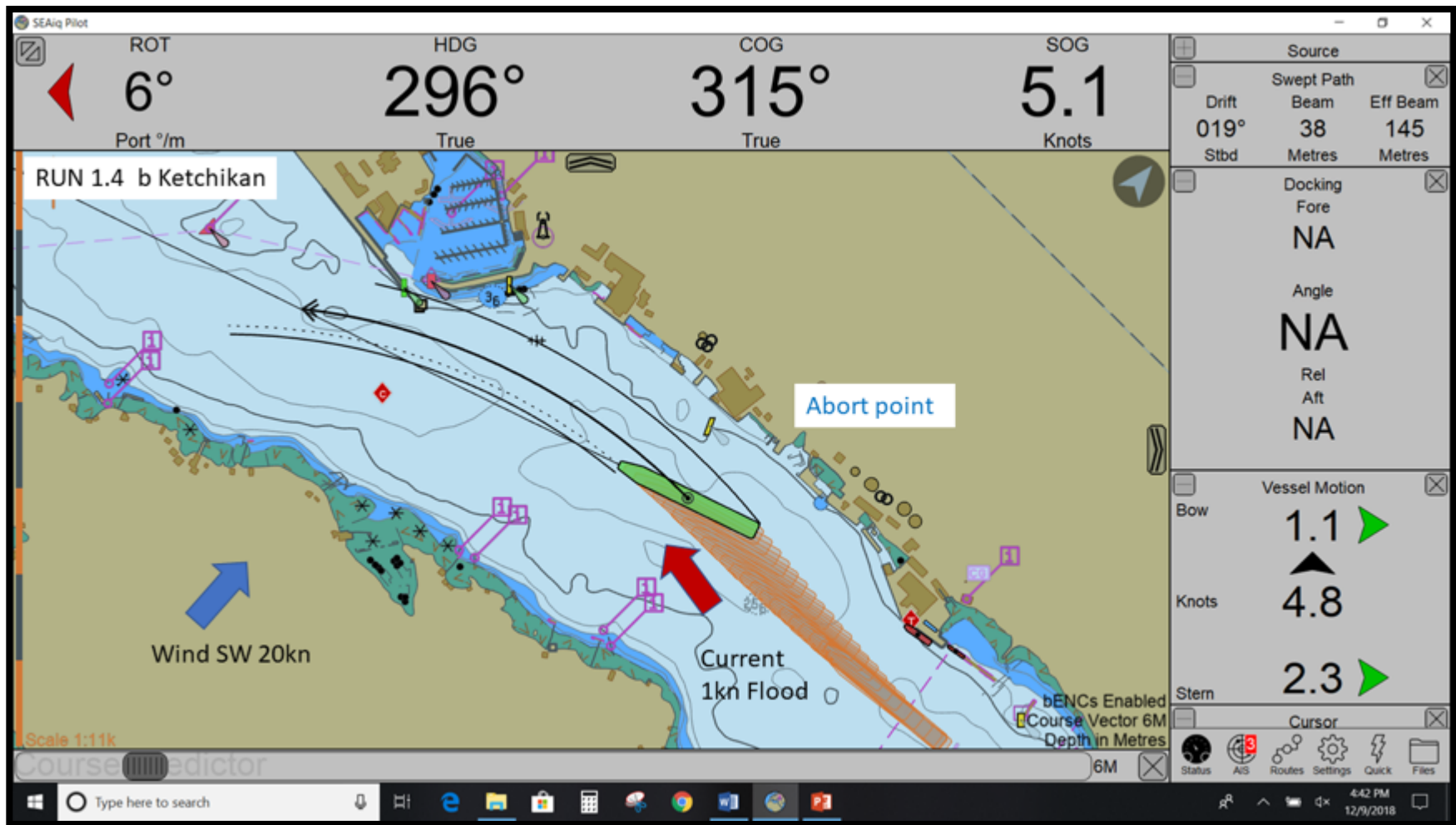


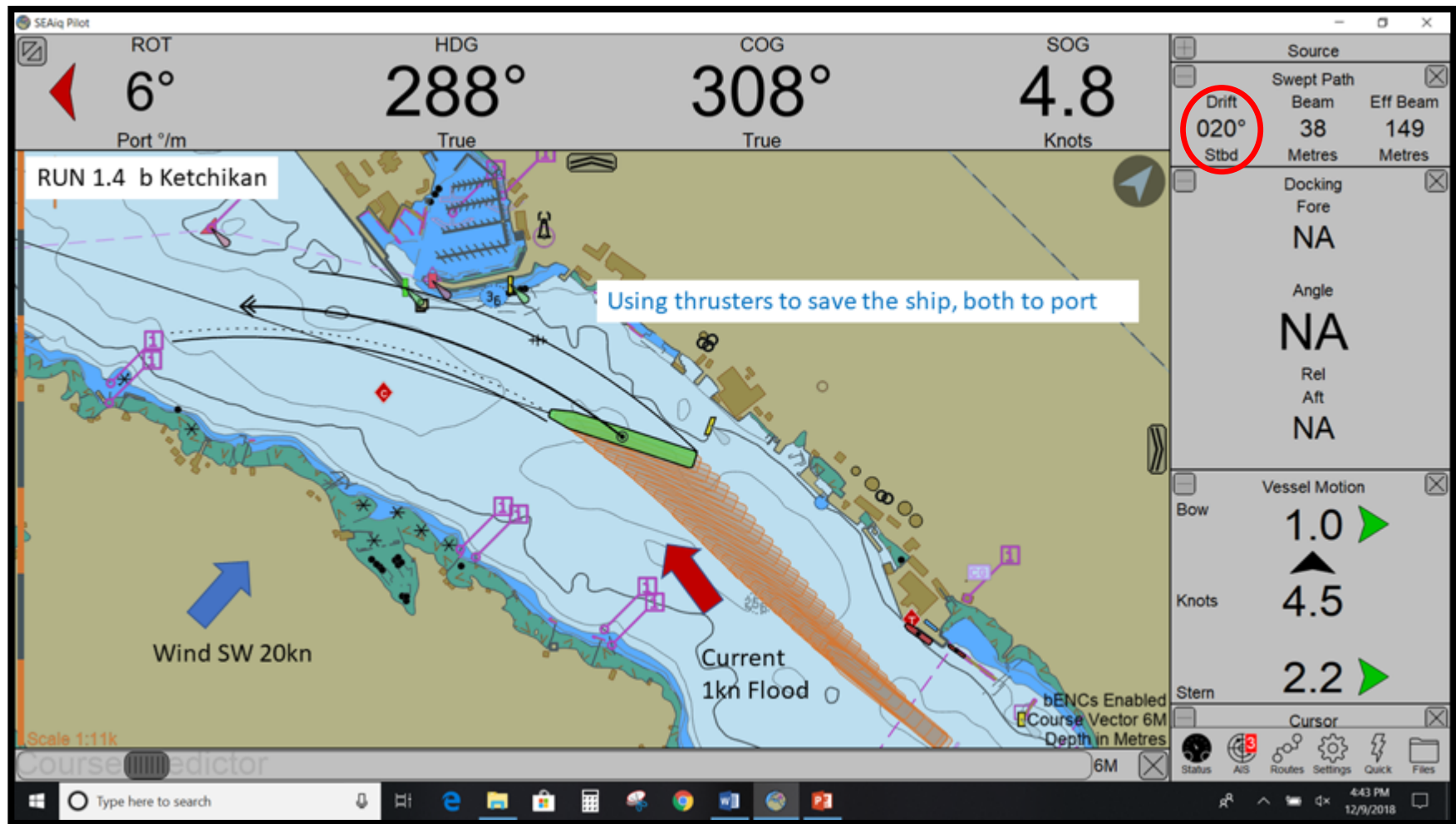
Run 1.4-B Ketchikan IB

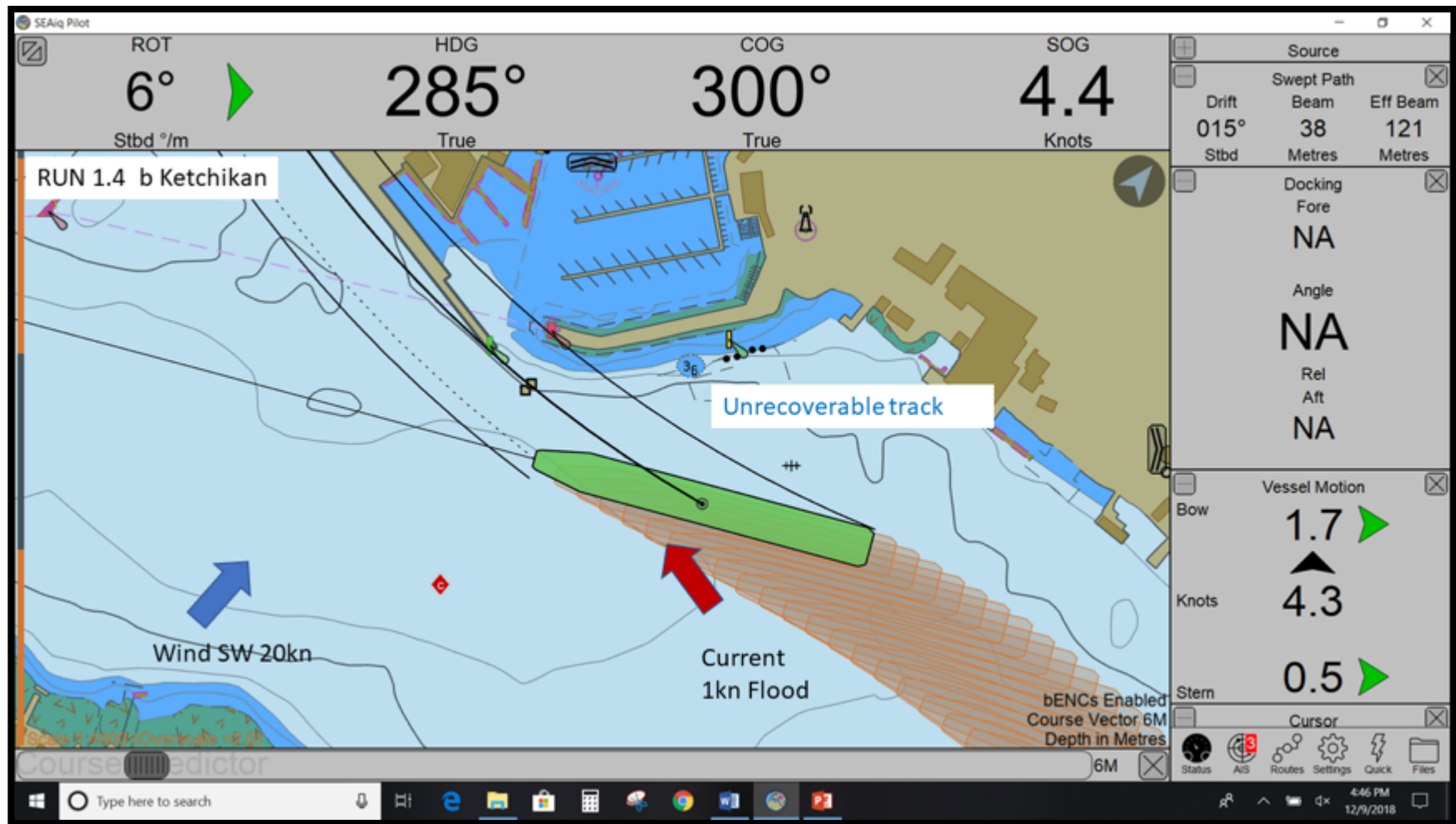
1.4b, Jump from CA Rocks to Dock Area, 20 kn SSE

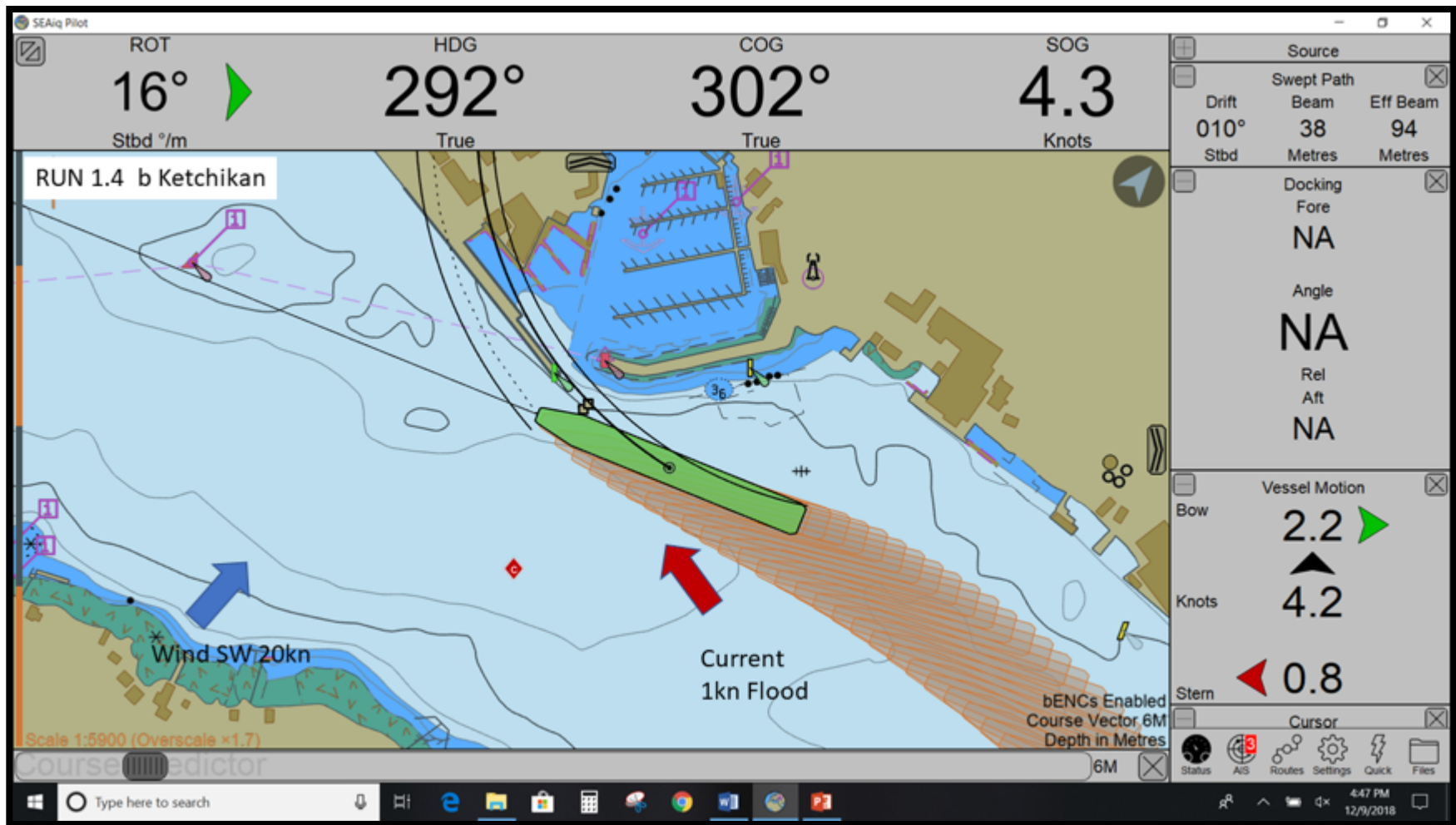
Sunday 12/9/2018

9th run







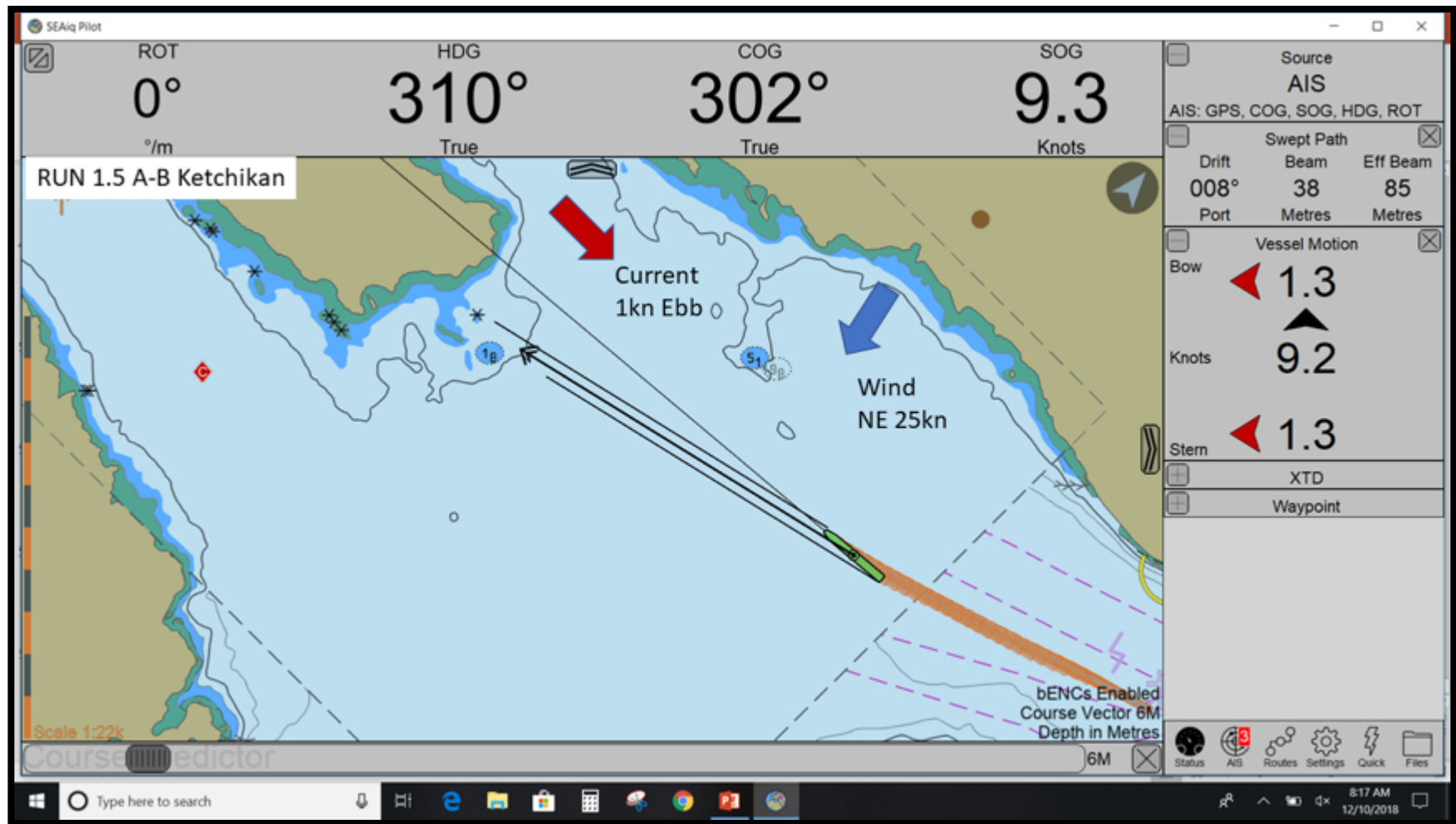


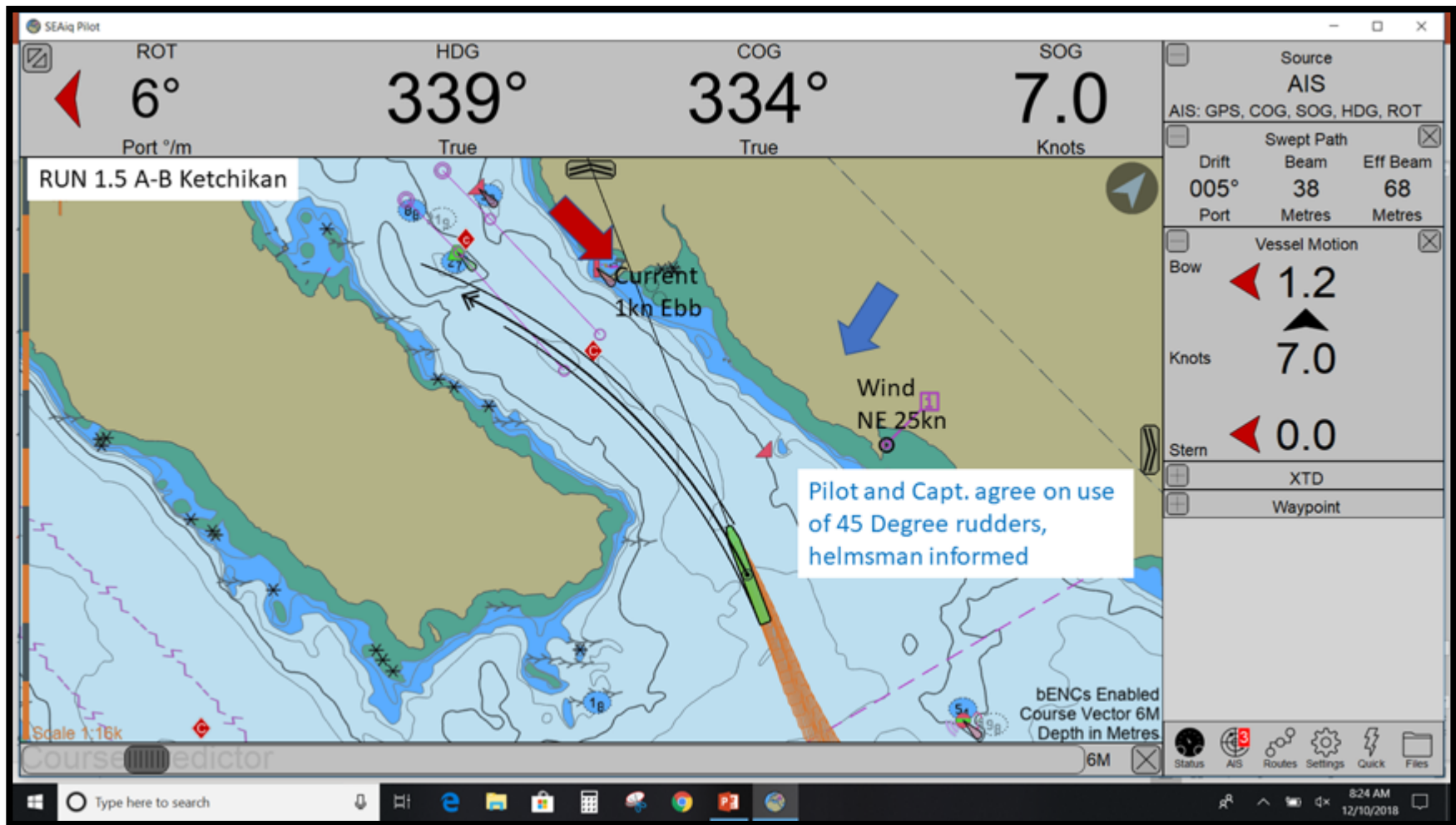
Run 1.5 A-B Ketchikan IB, NE 25kn, 1kn Ebb

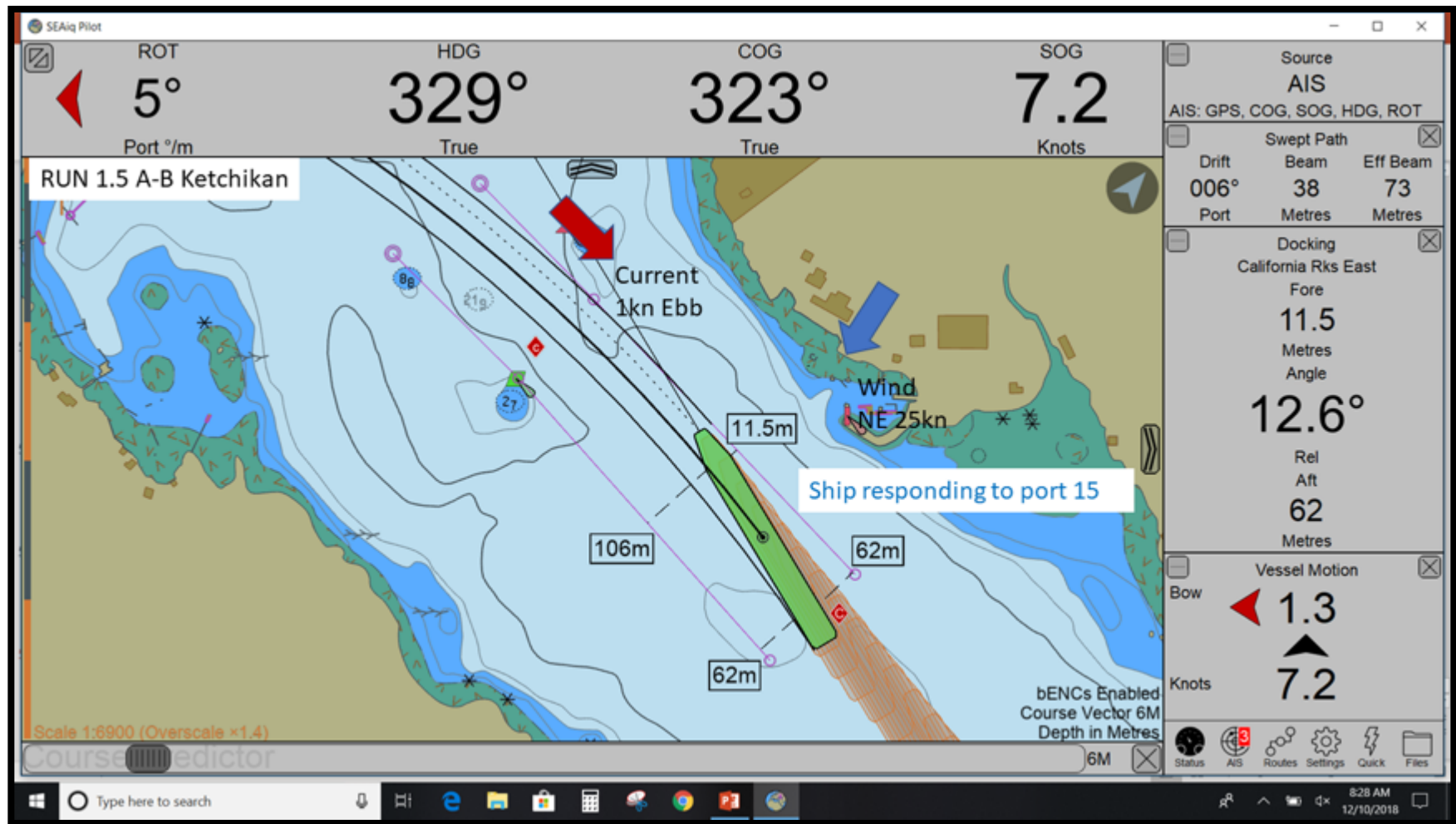
1.5a-b, NE 25kn 1kn Ebb, Ketchikan

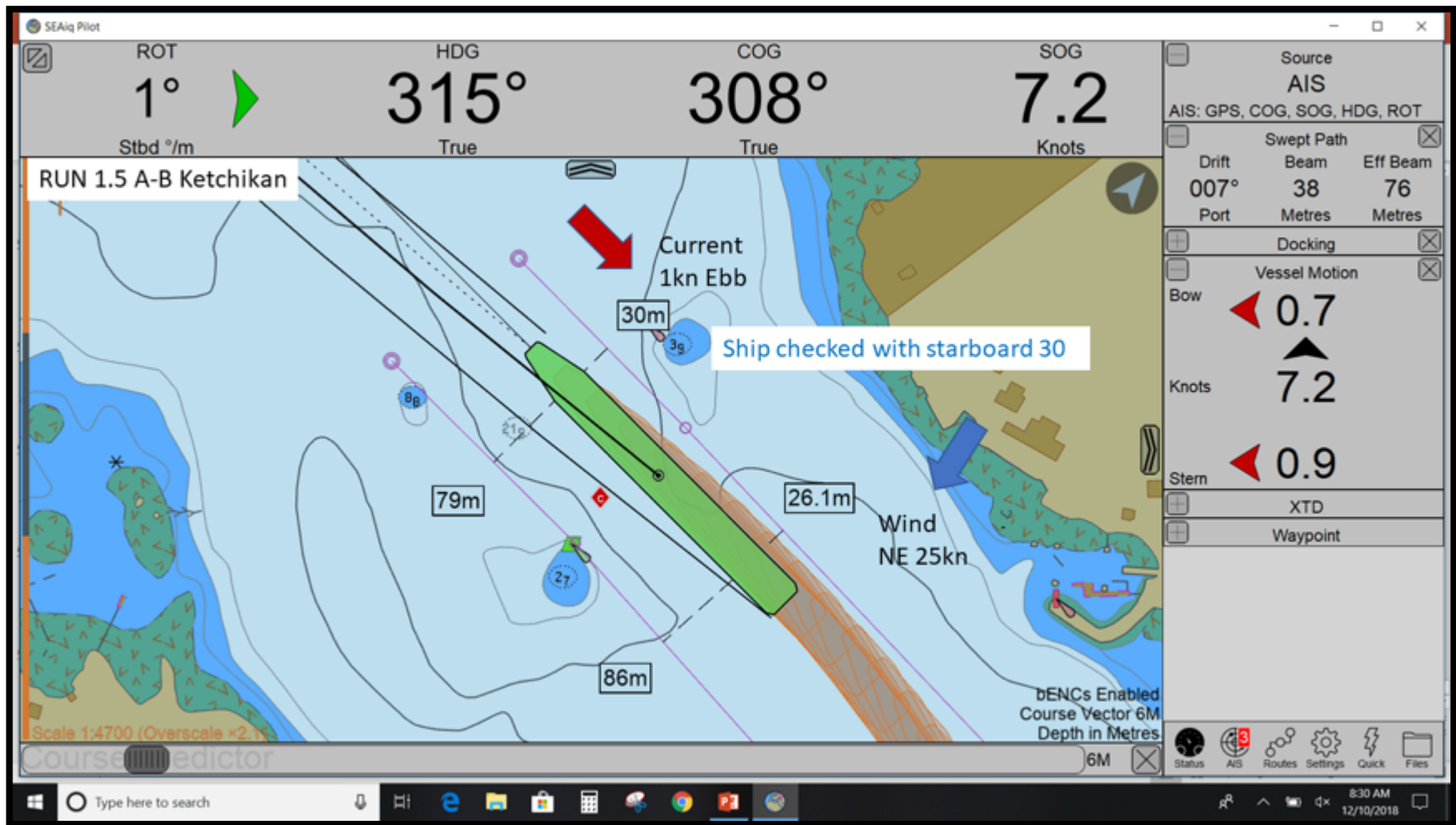
Monday 12/10/2018

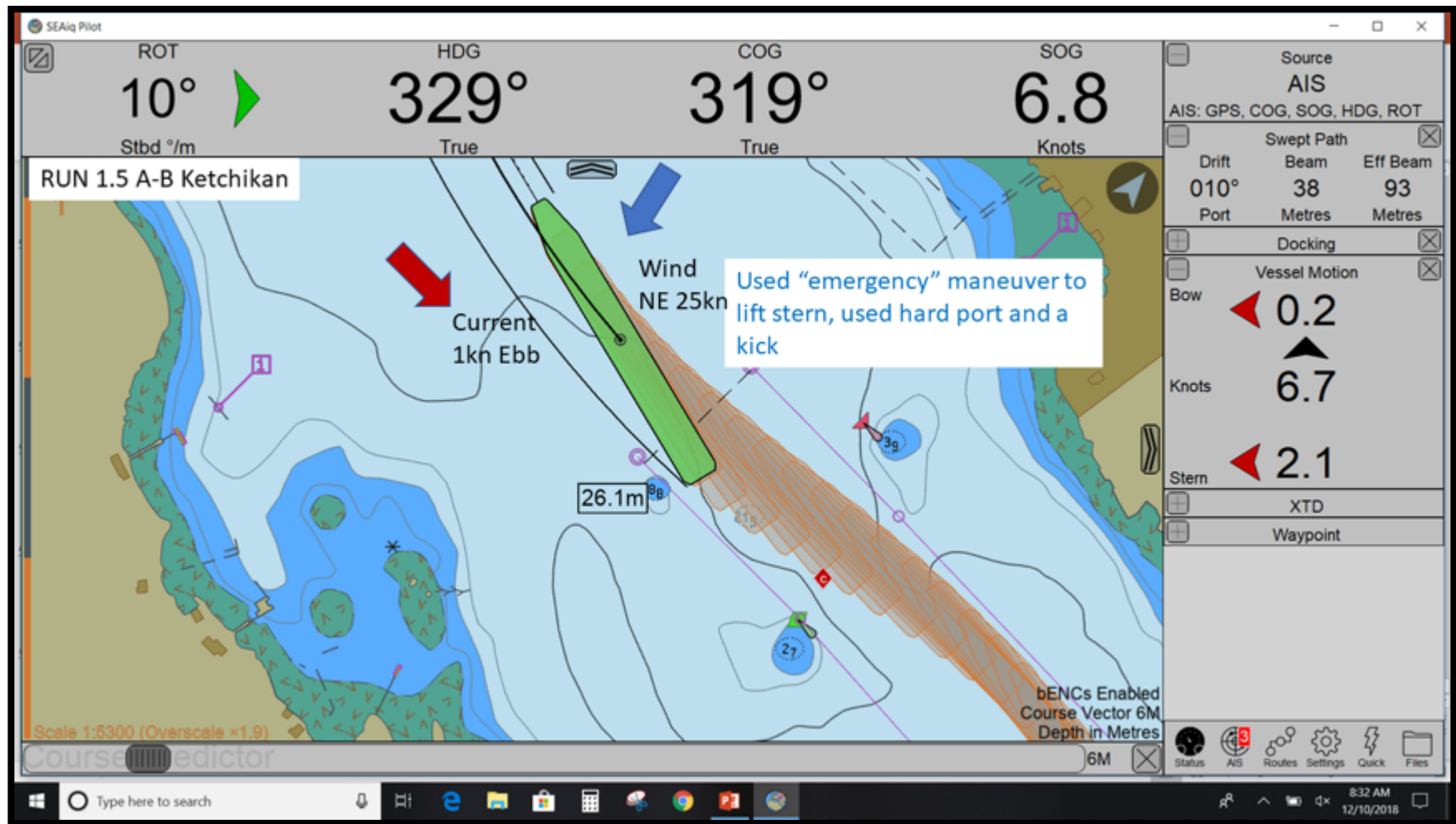
1st run

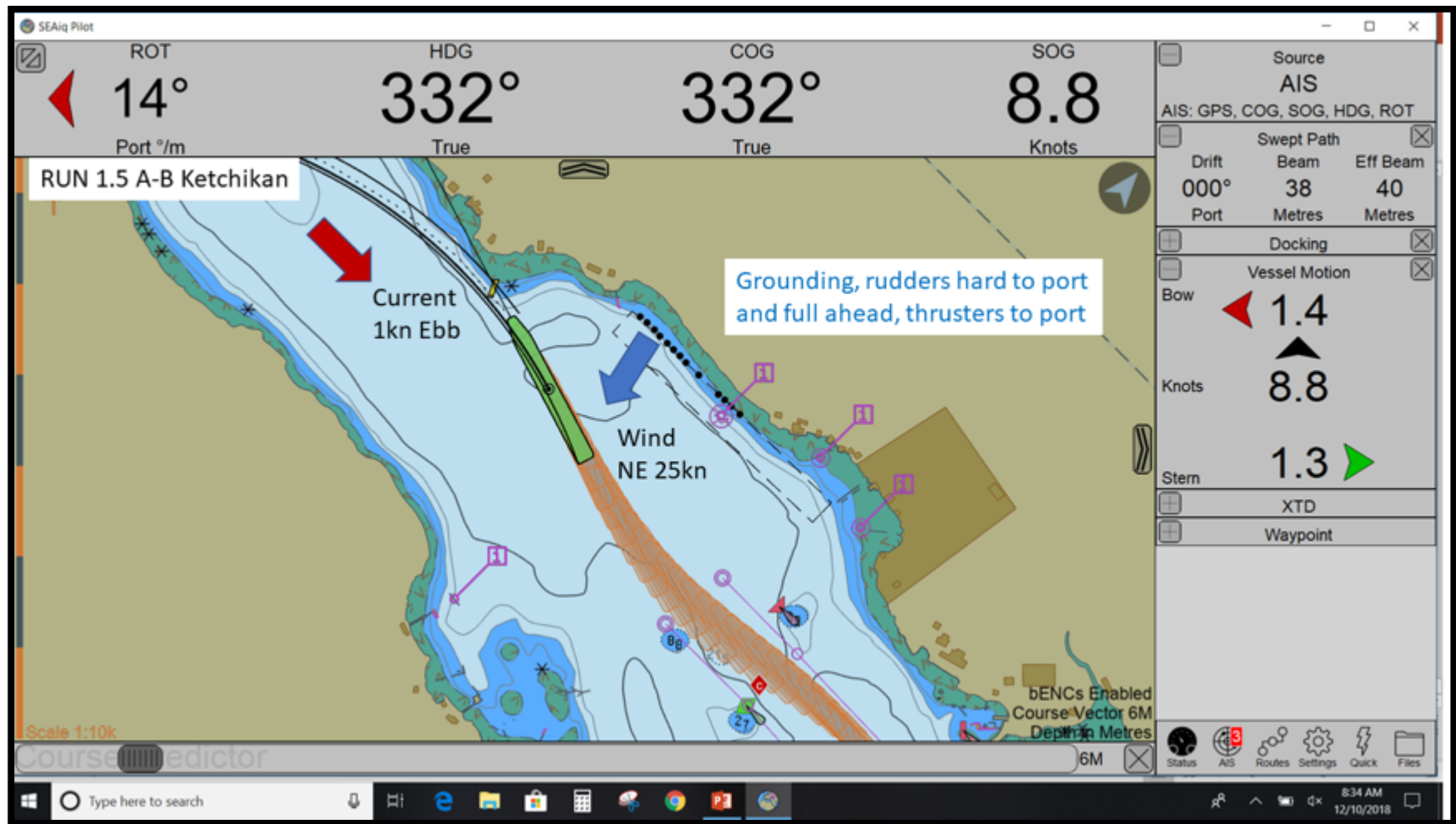










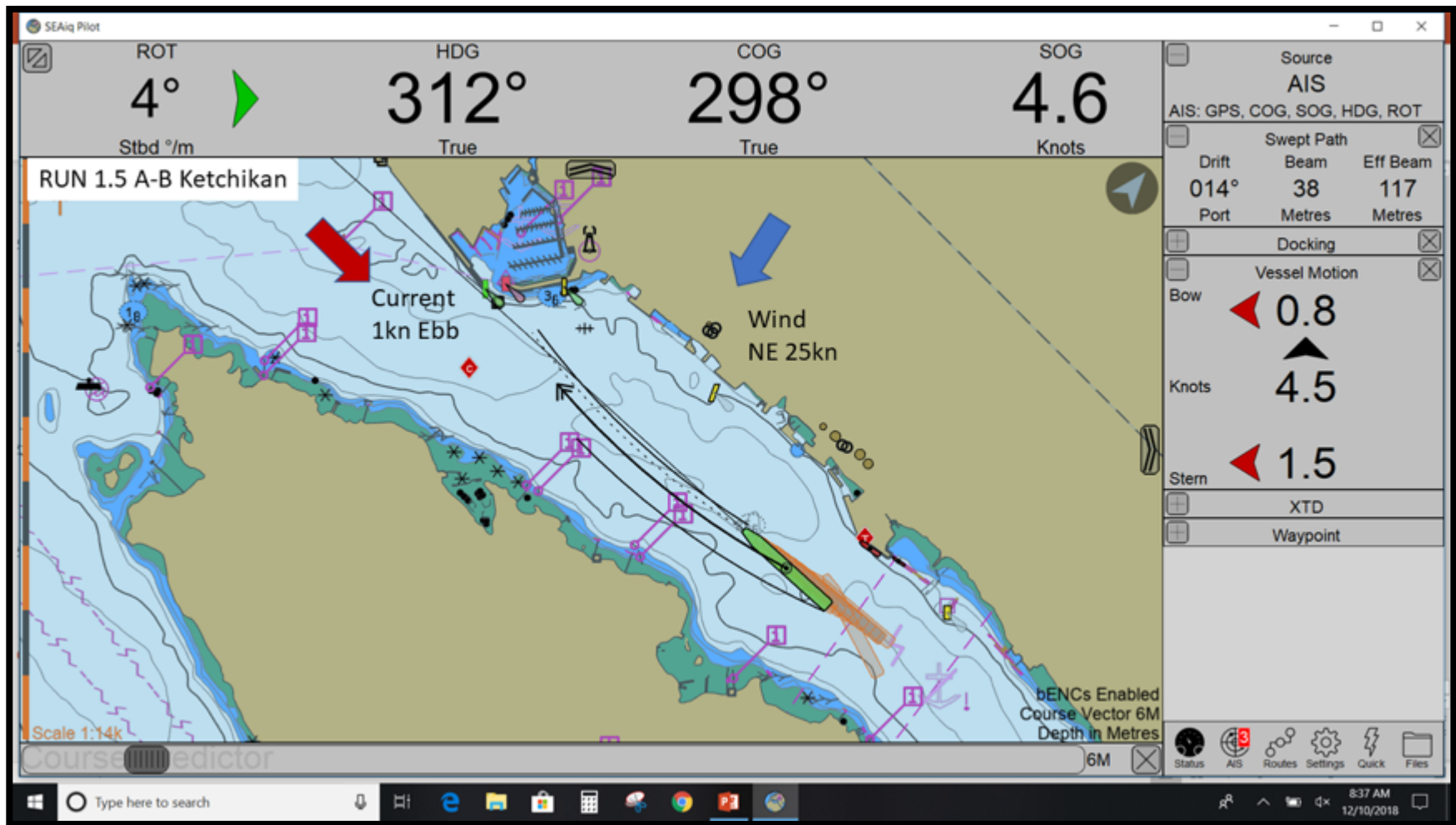


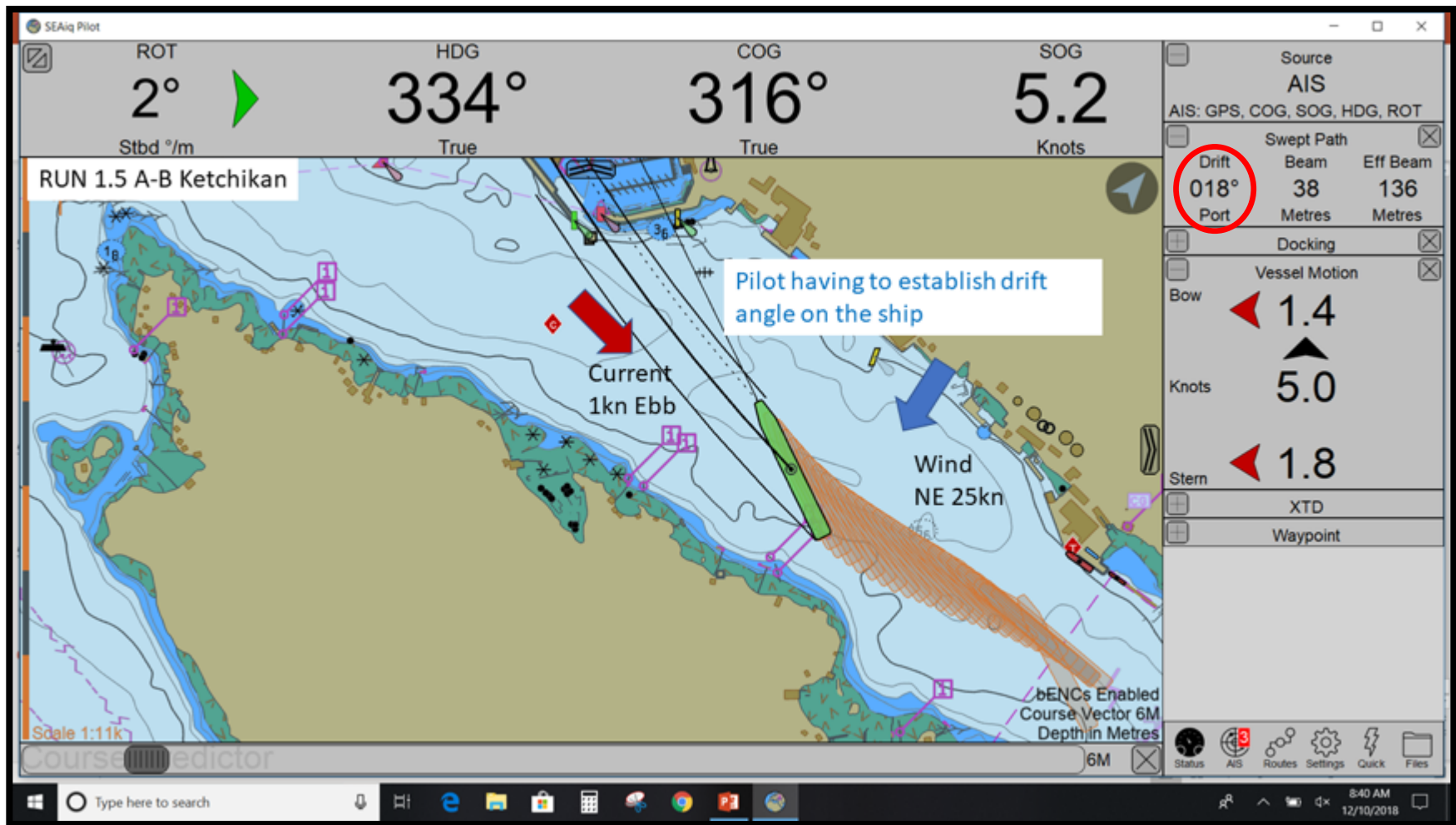
Run 1.5B Ketchikan IB, NE25, 1kn Ebb

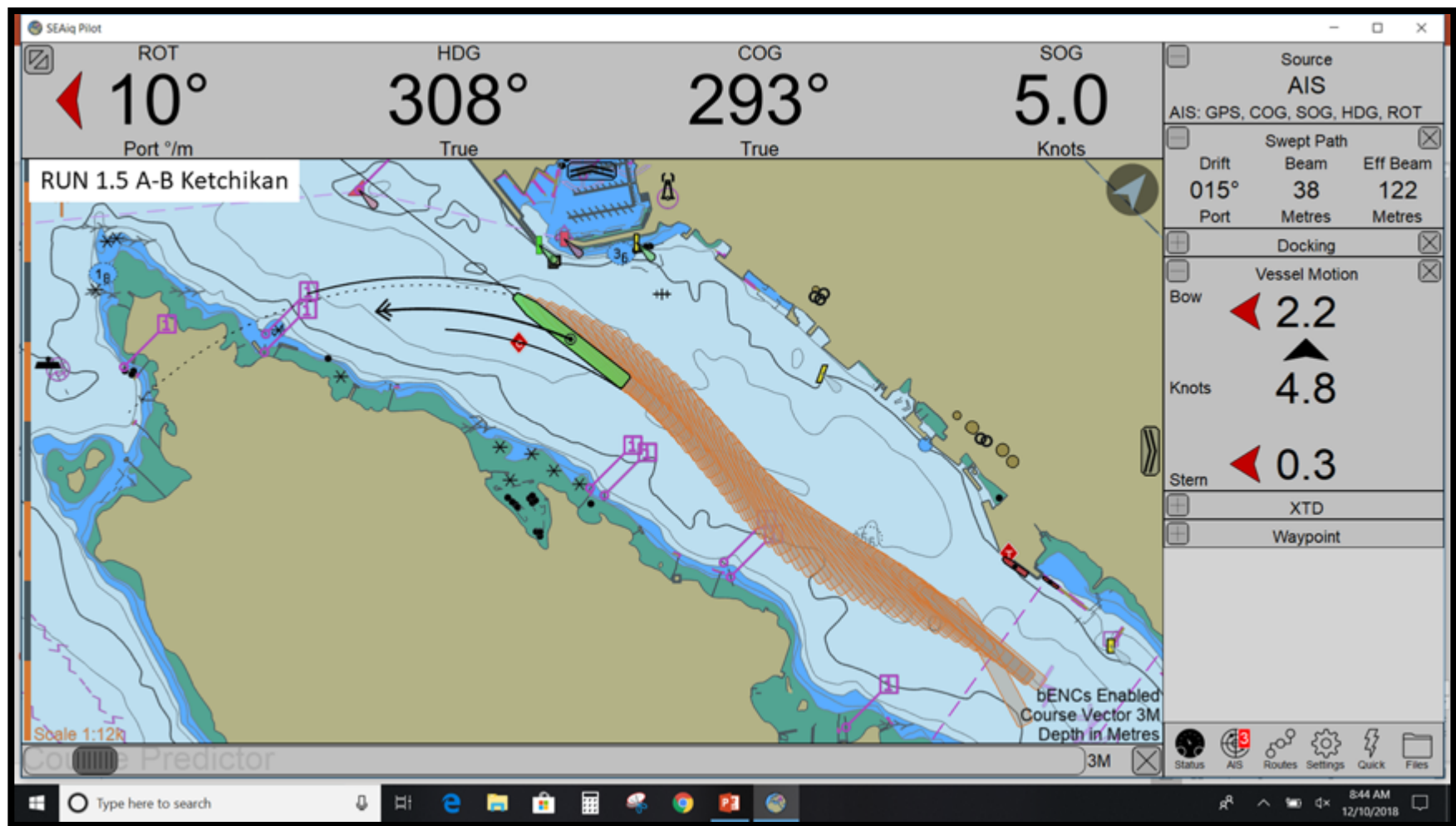
1.5b, NE 25kn 1kn Ebb, Ketchikan

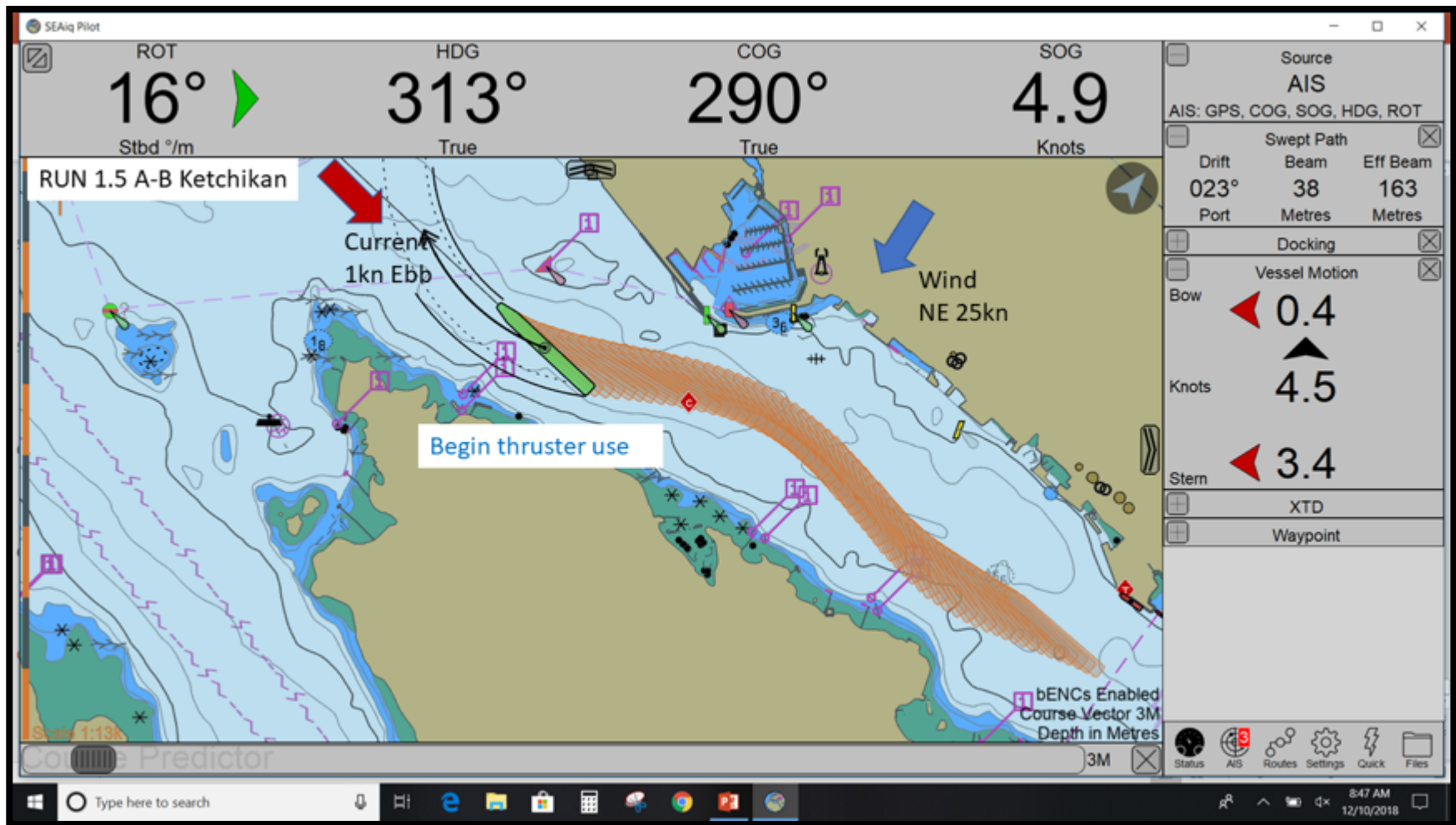
Monday 12/10/2018

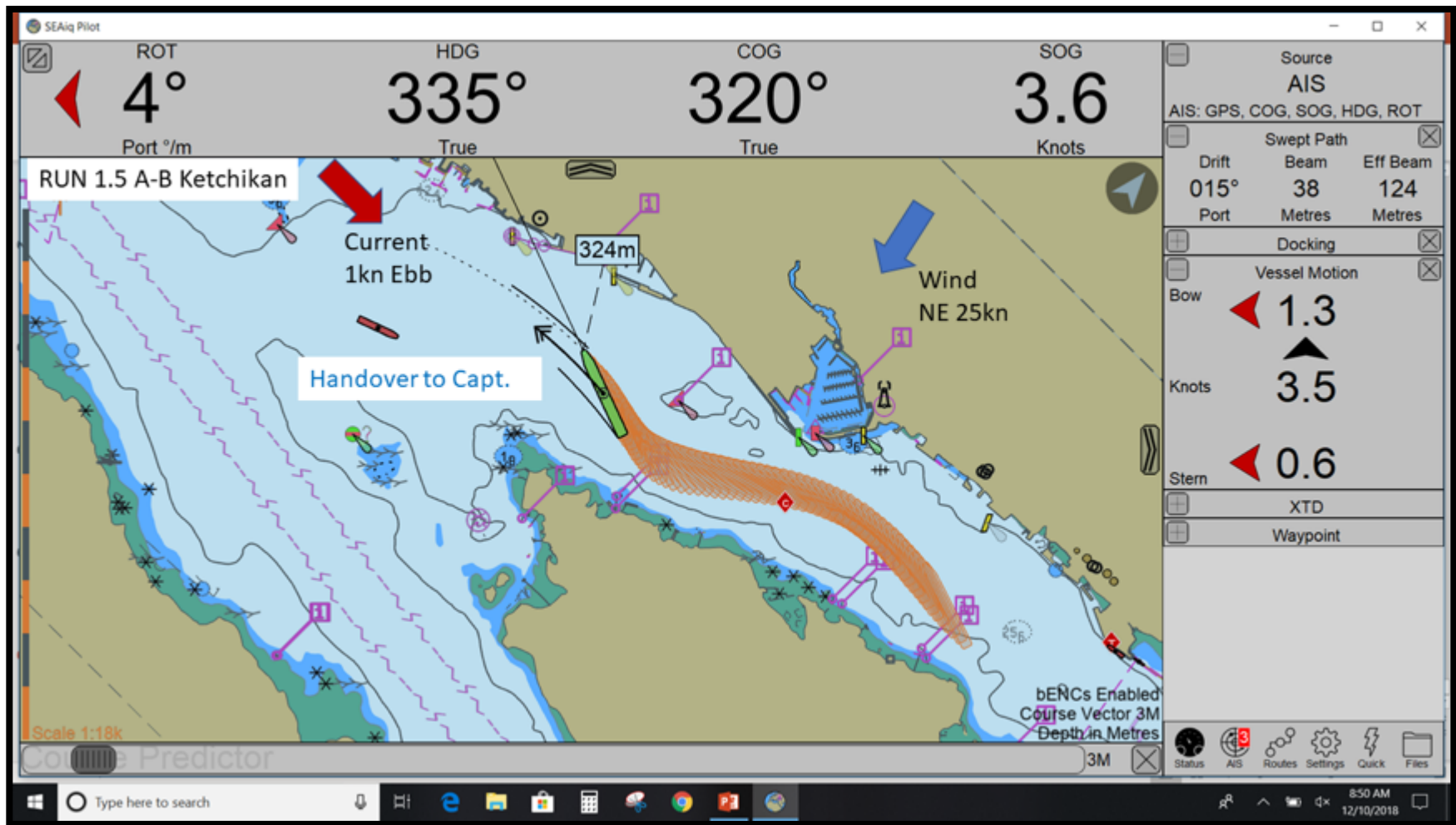
2nd run

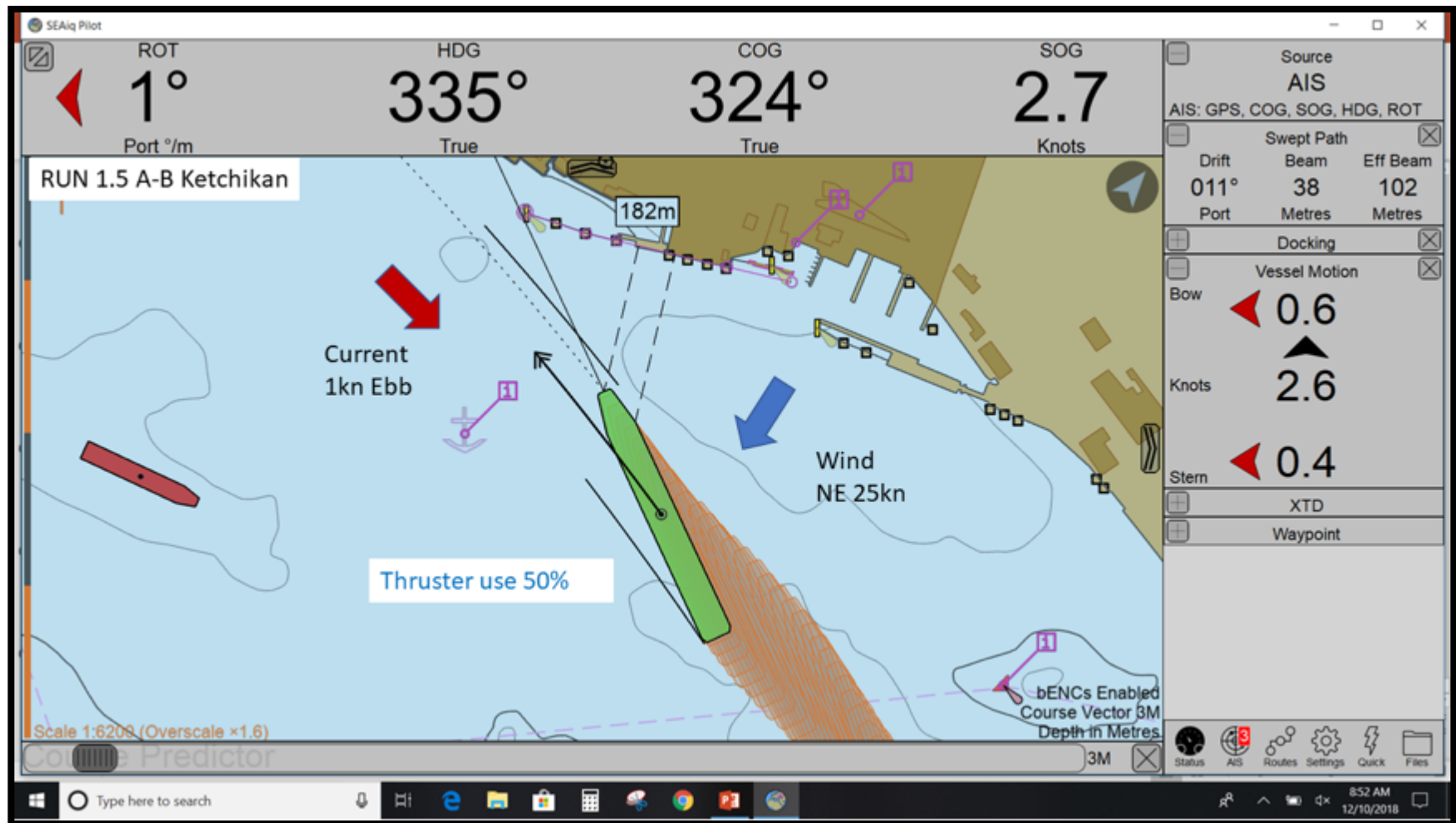


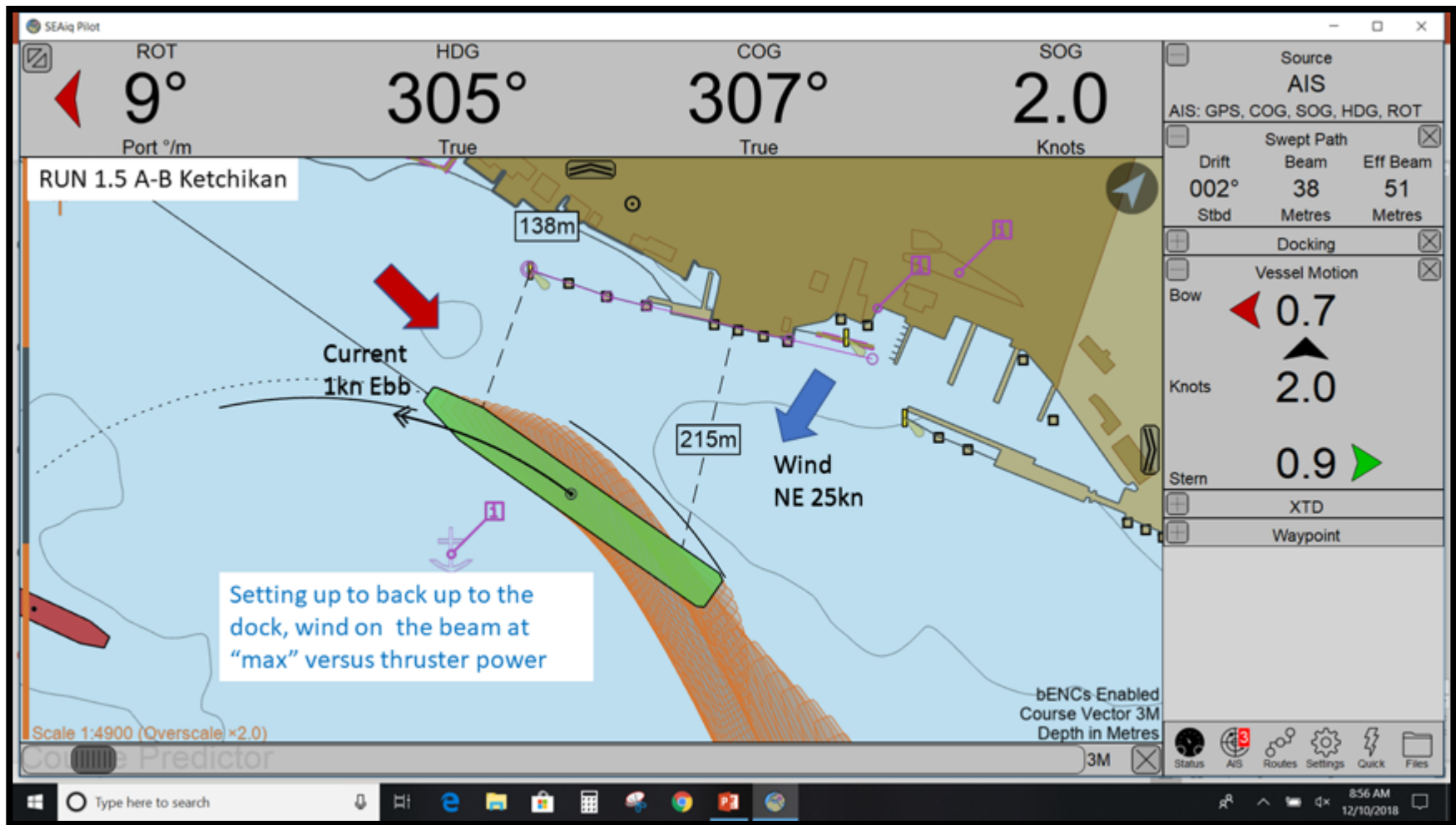


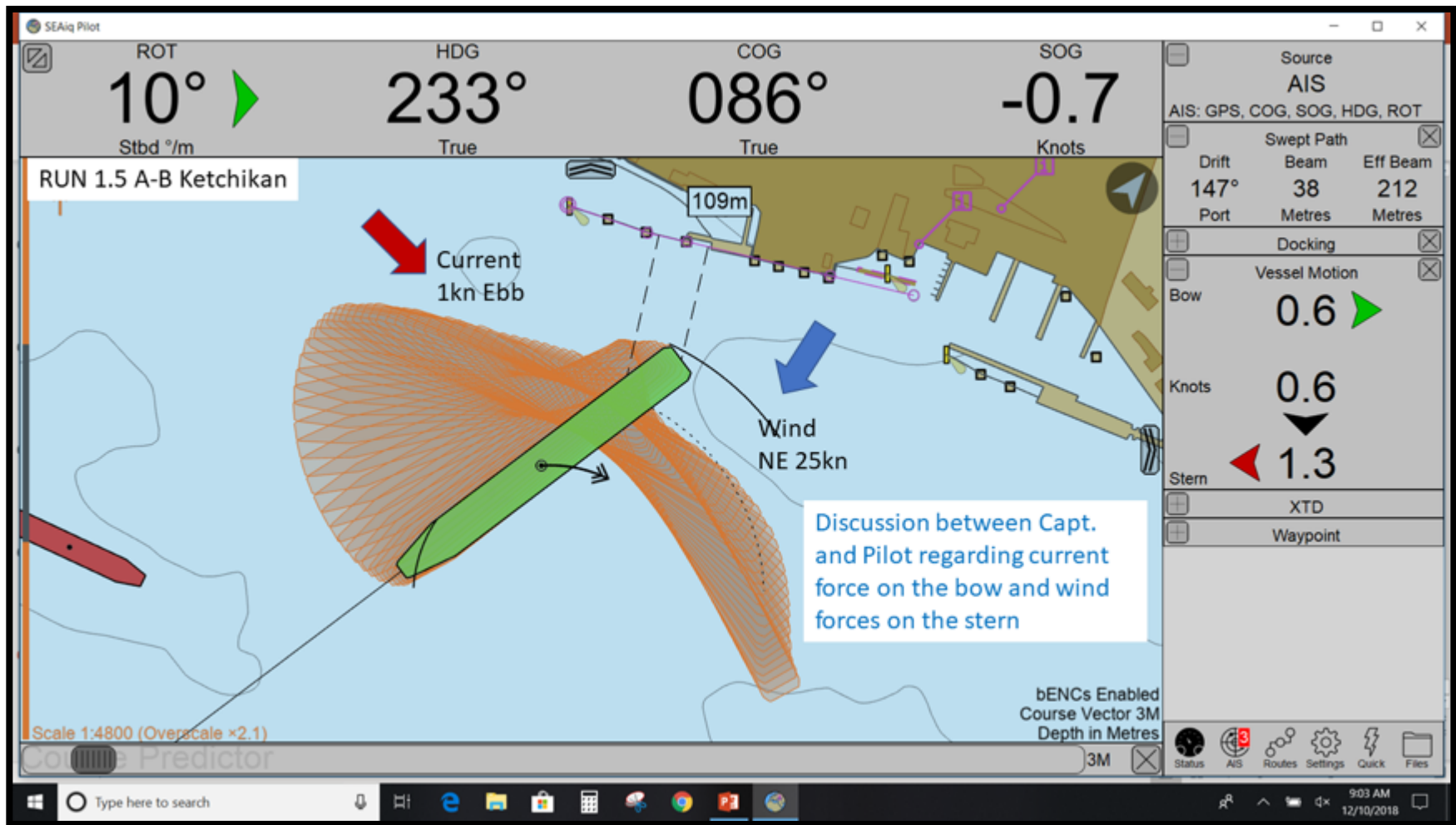


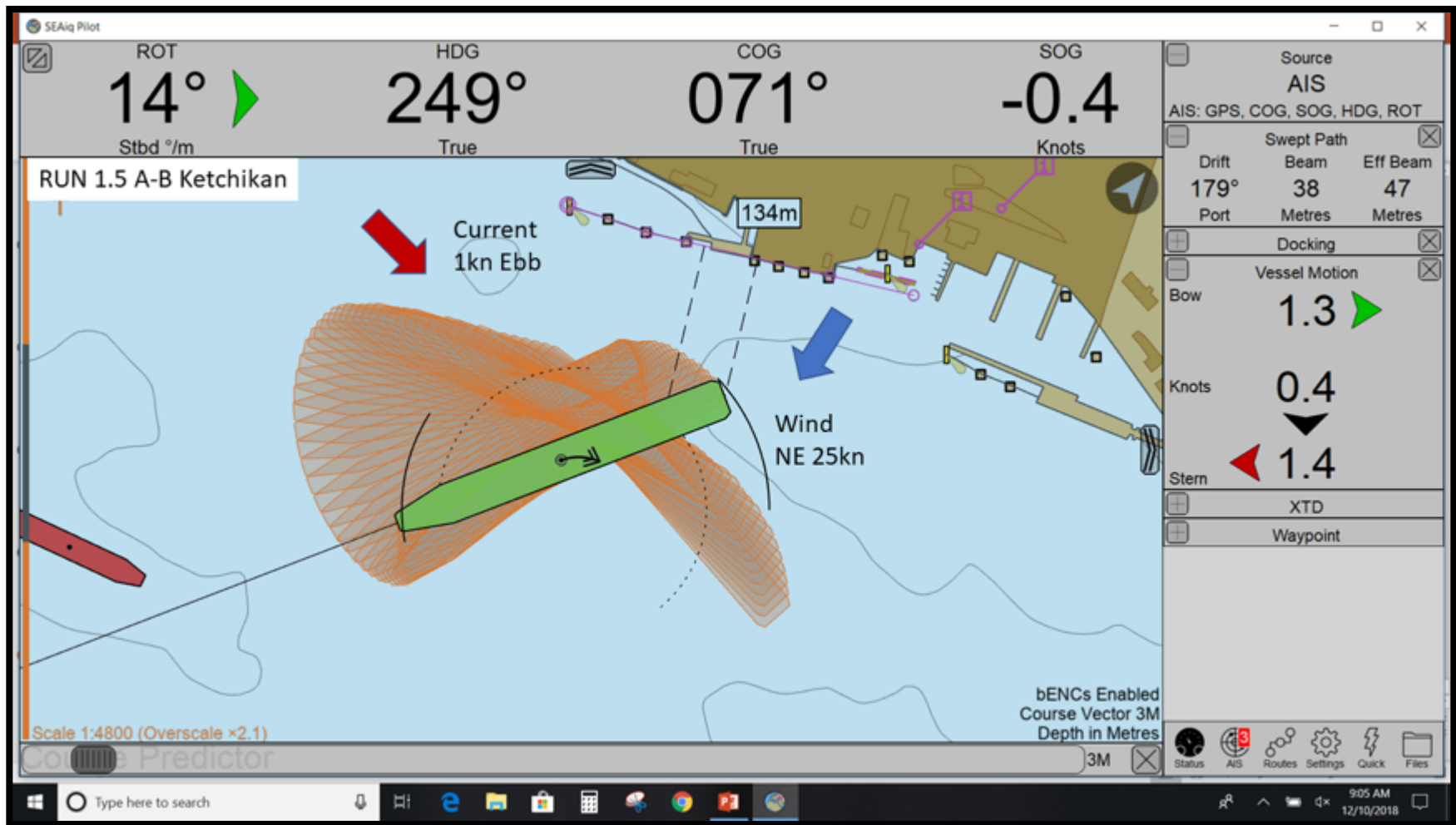










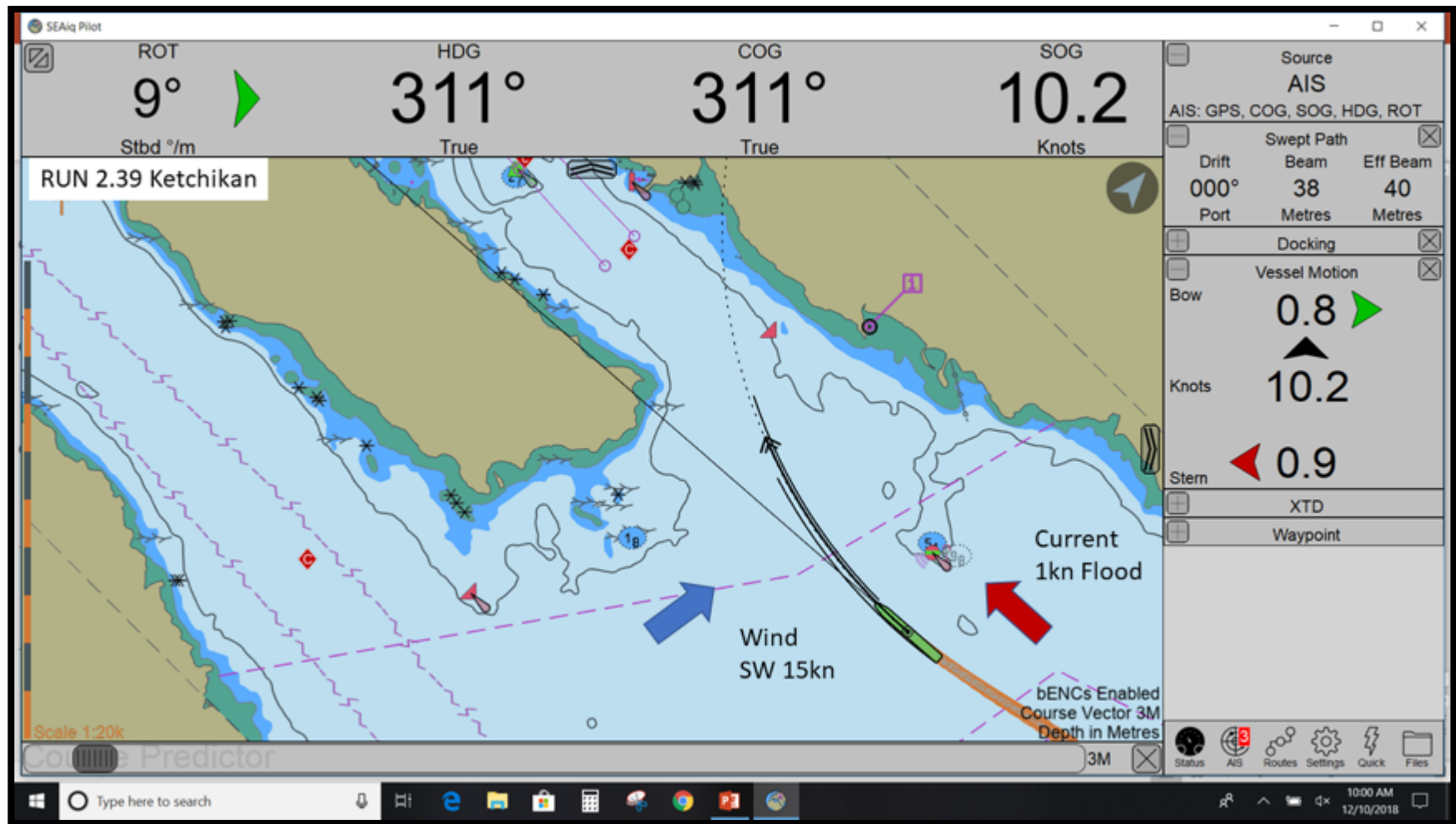


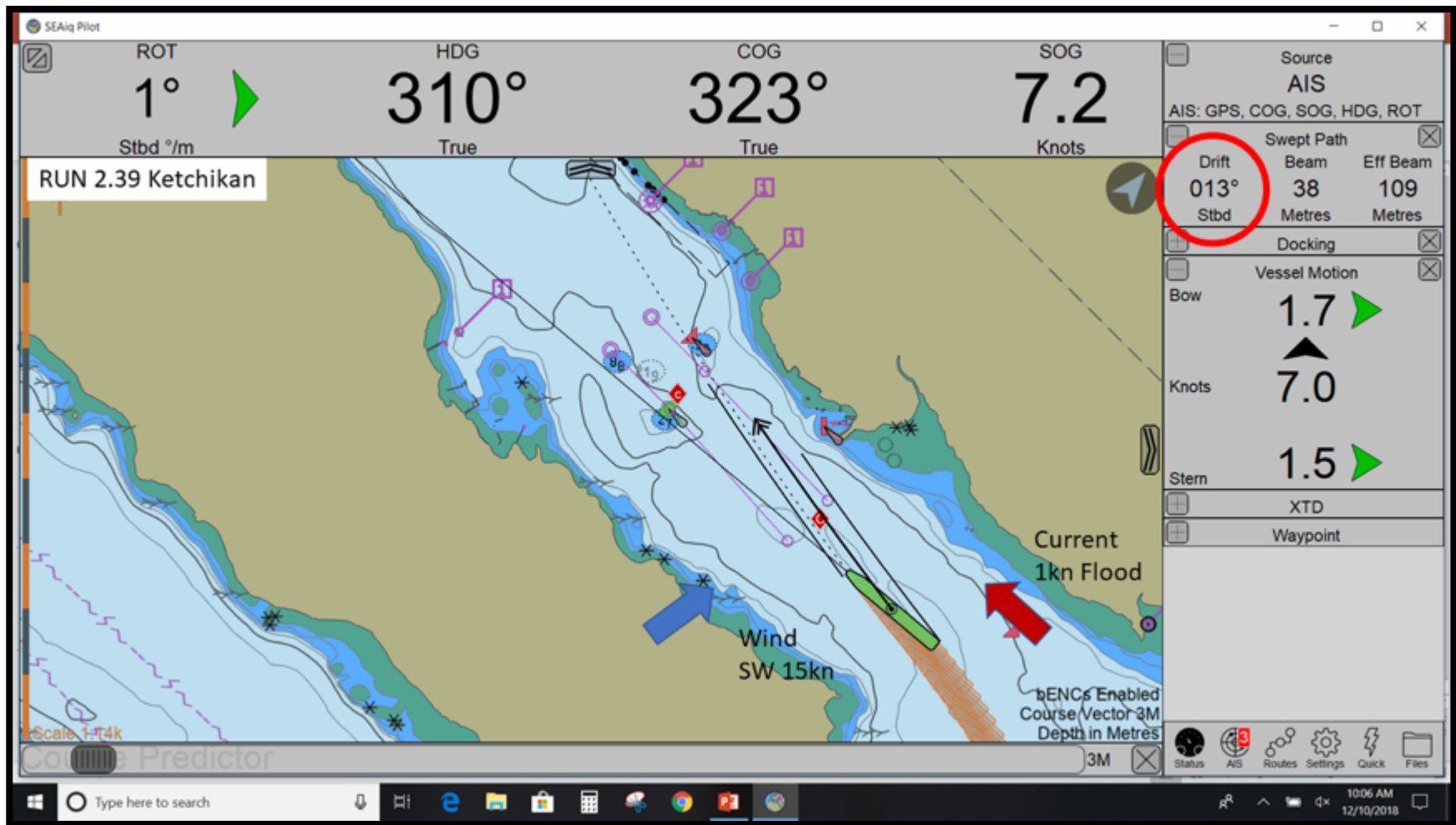
Run 2.39B Ketchikan IB SW15, 1kn Flood

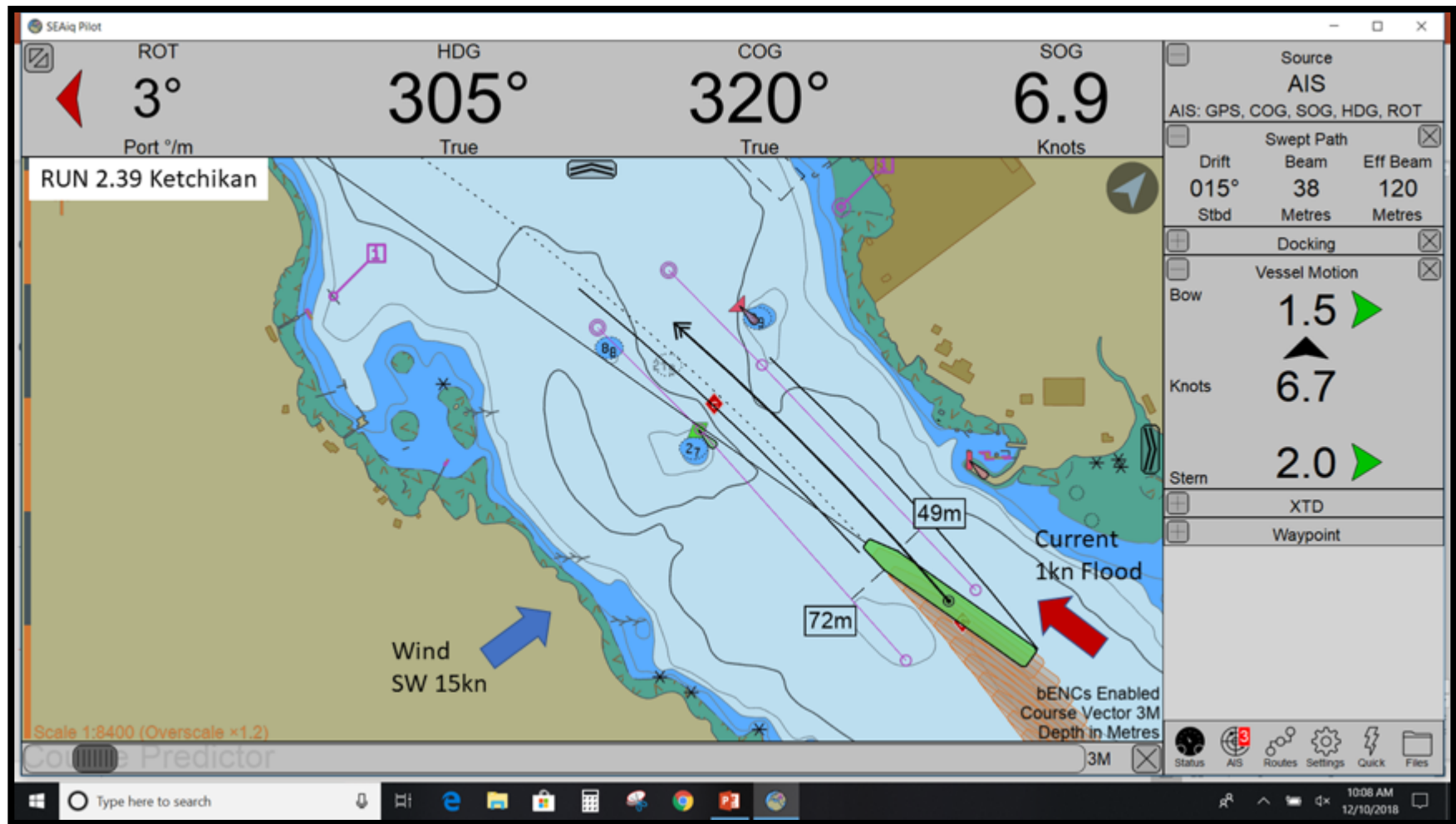
2.39 SW15 1kn Flood, Ketchikan

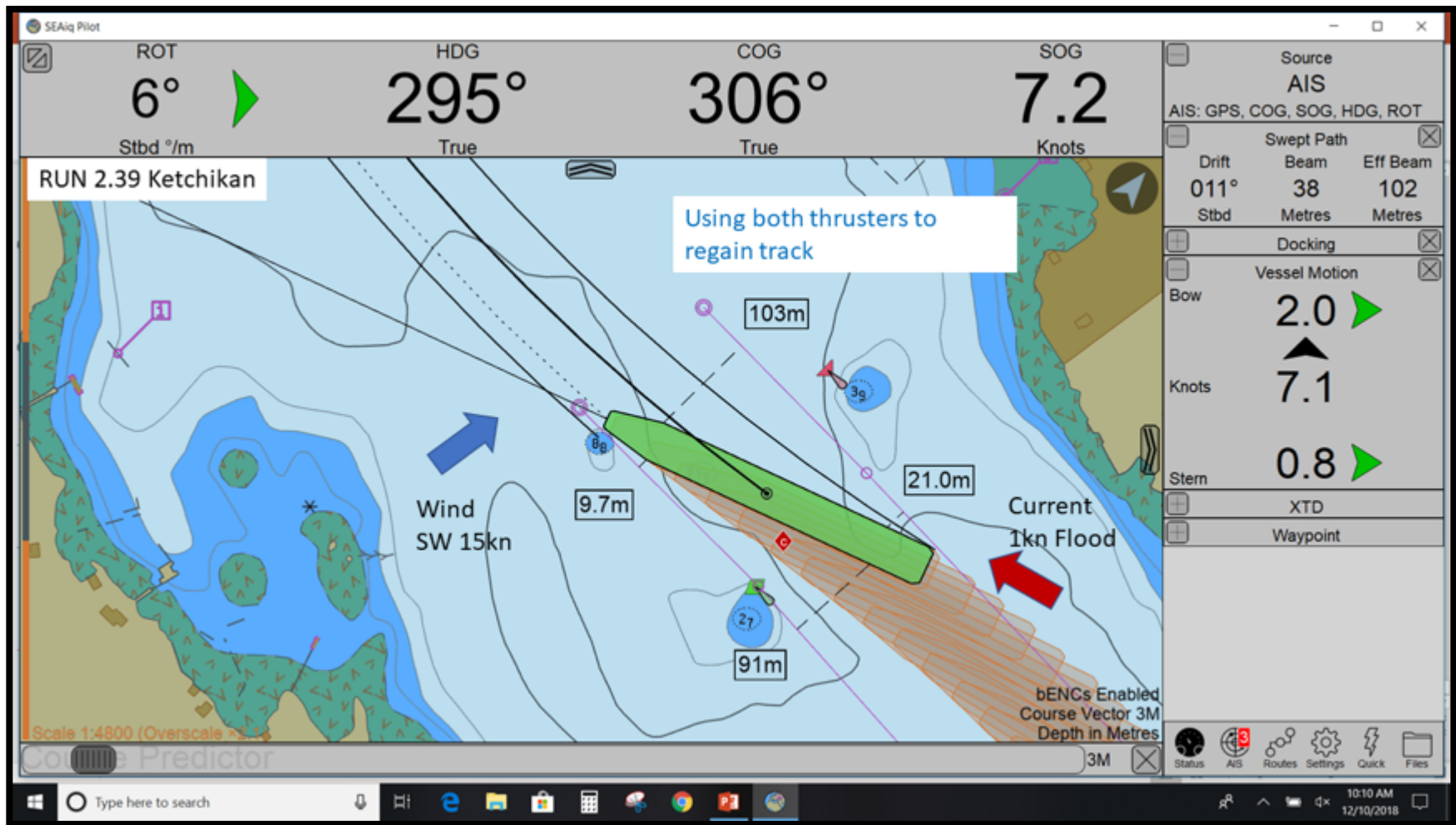
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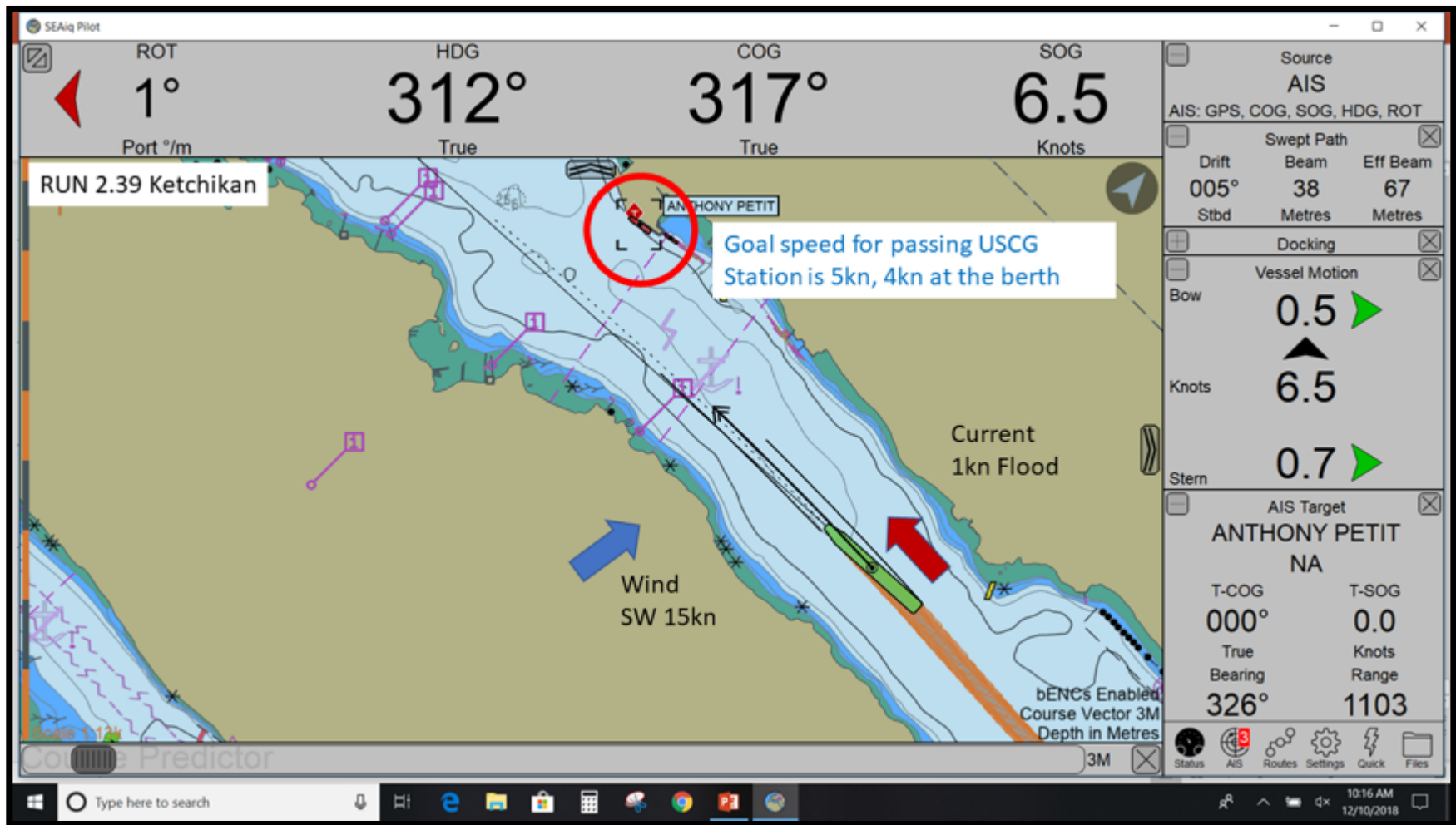


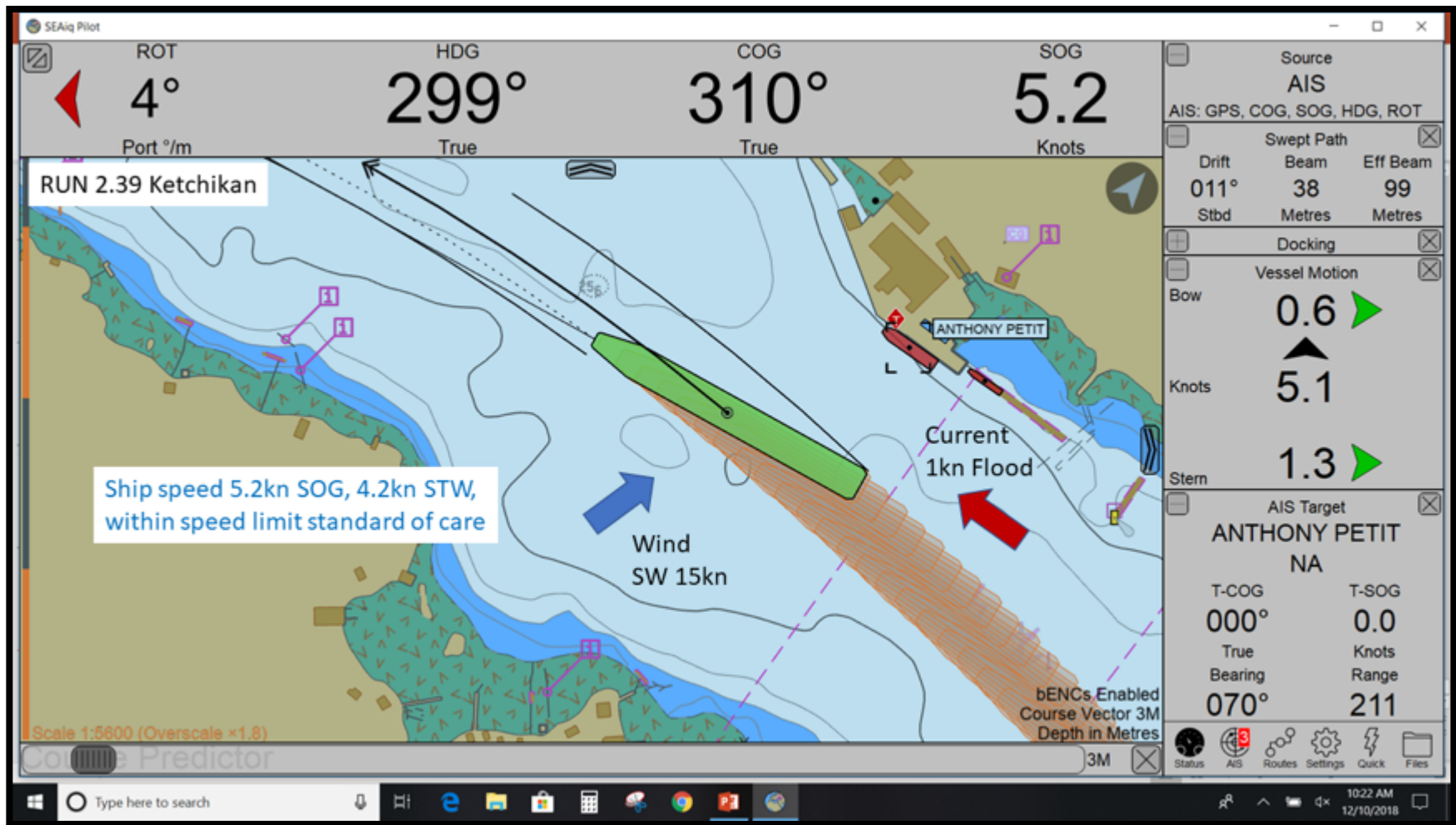


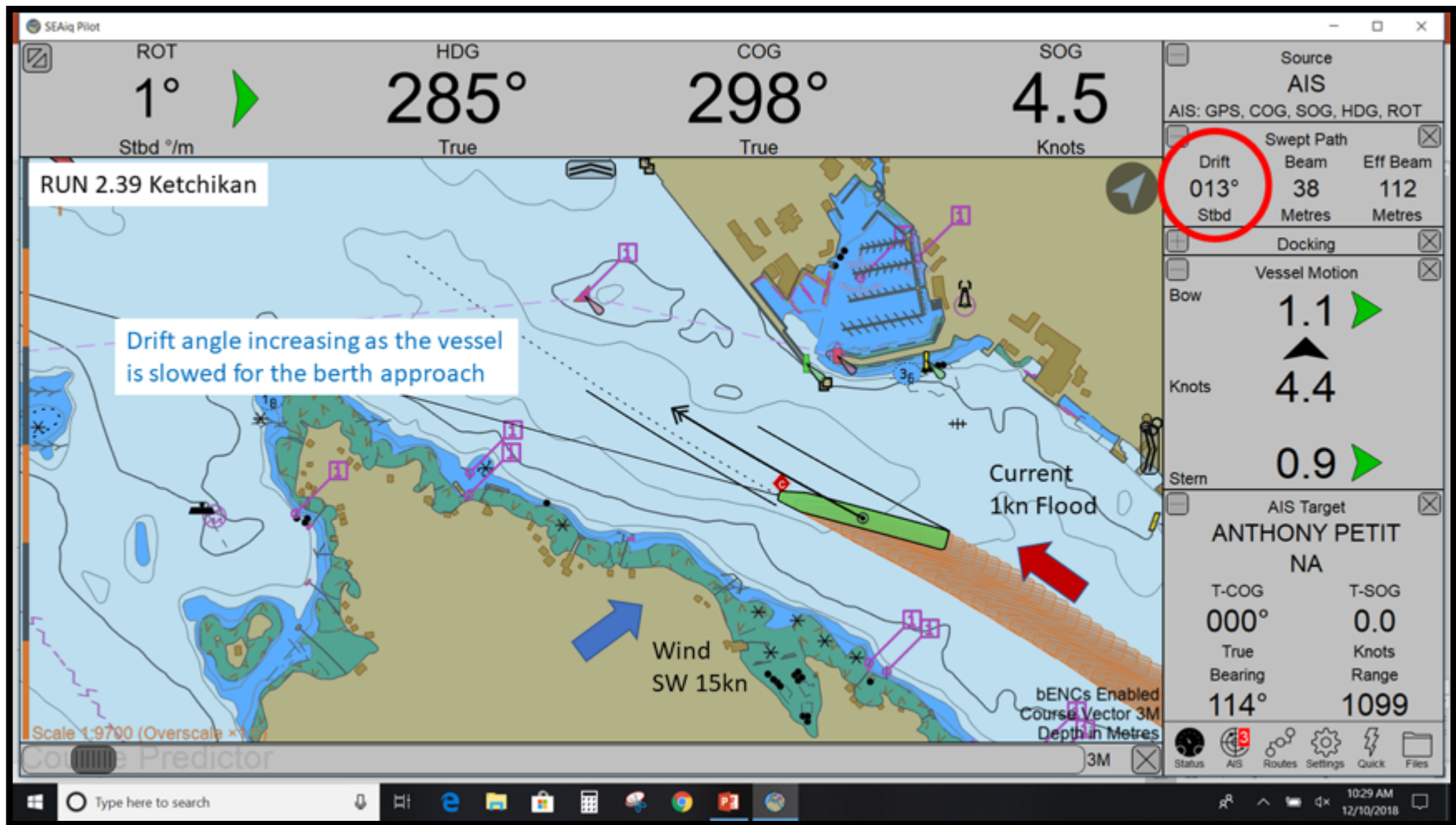


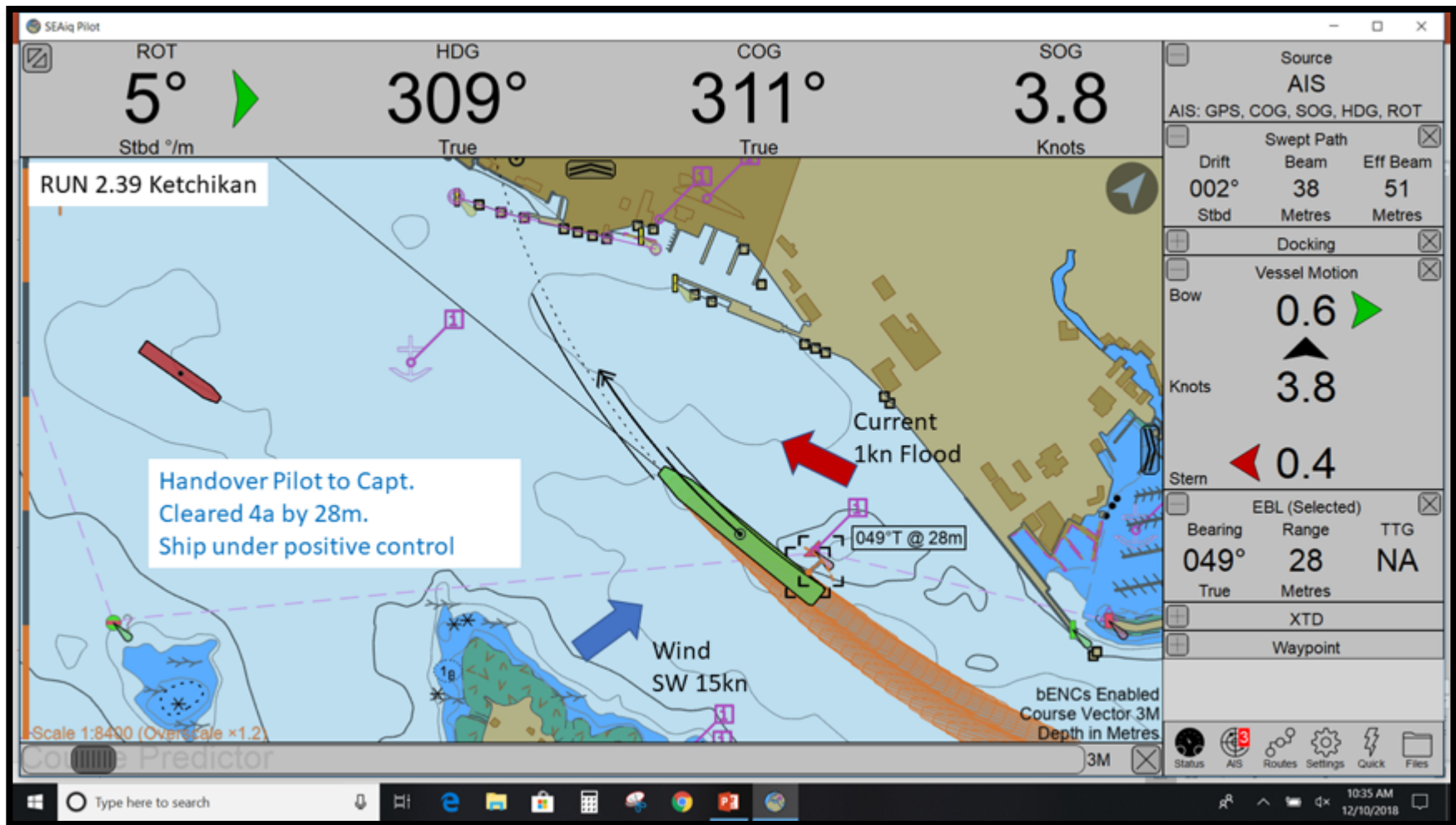


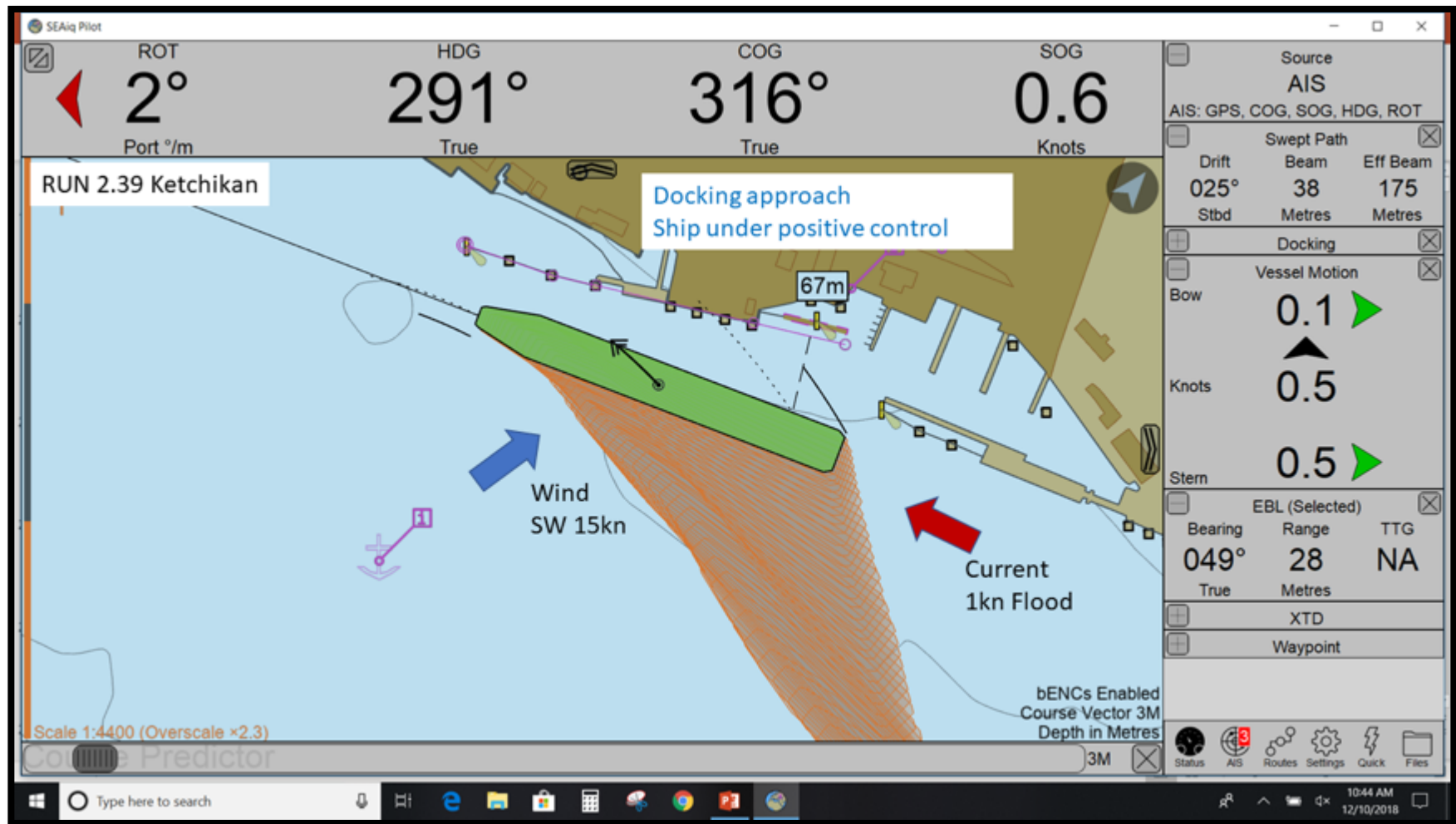












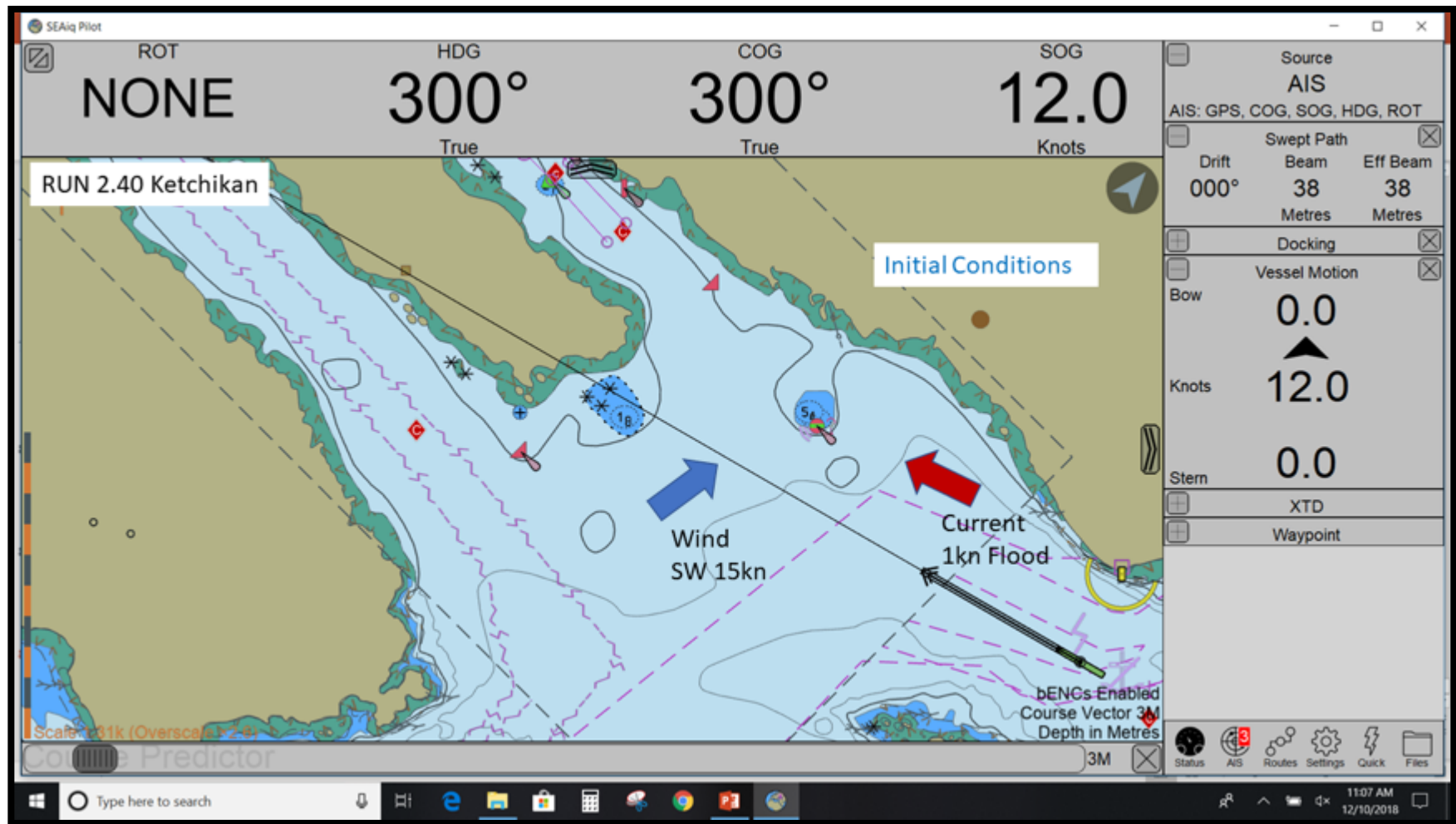
Run 2.40 Ketchikan, SW 15, 1kn Flood

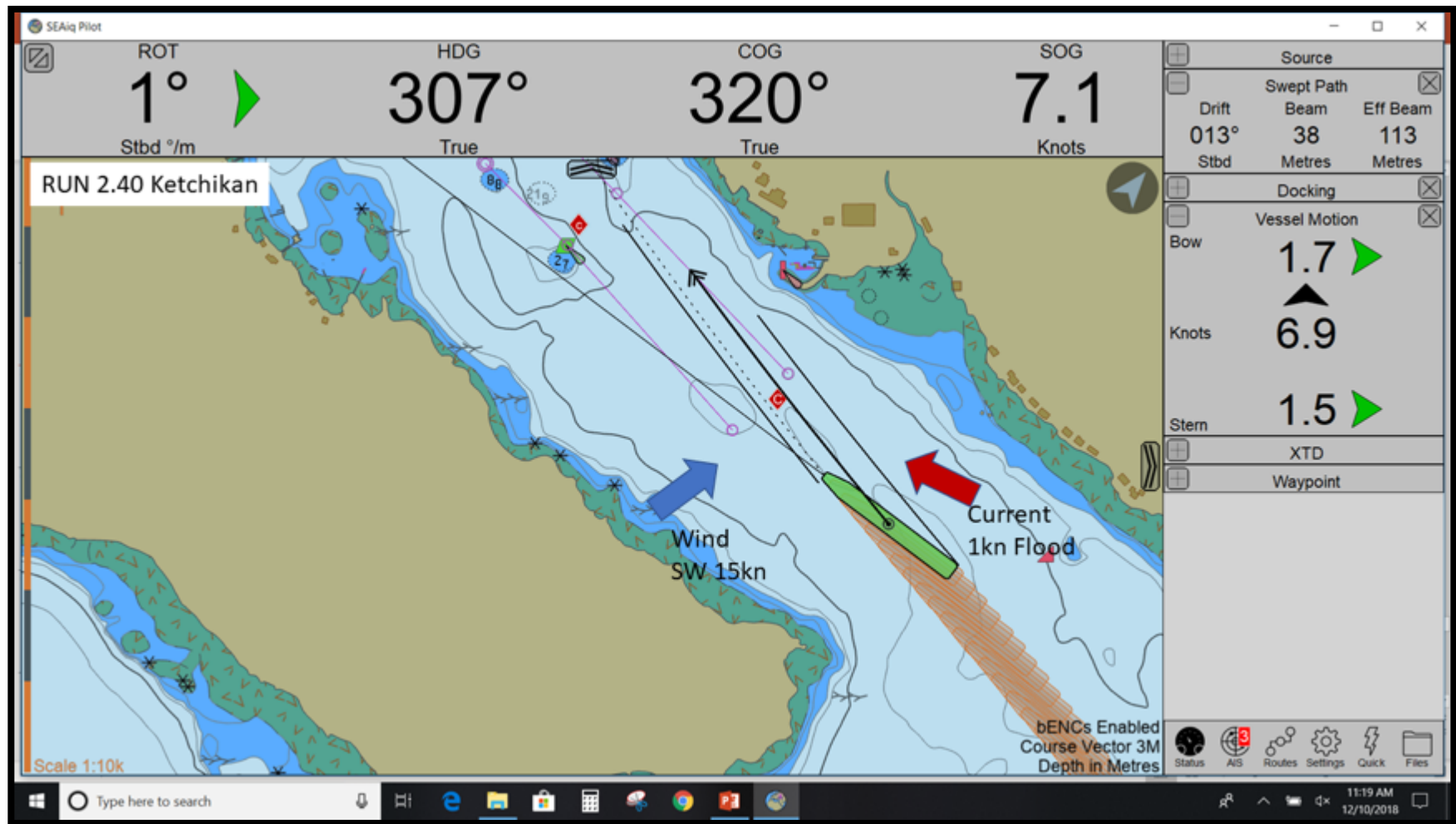
2.40 SW15 1kn Flood, Ketchikan

Same as before, different Pilot

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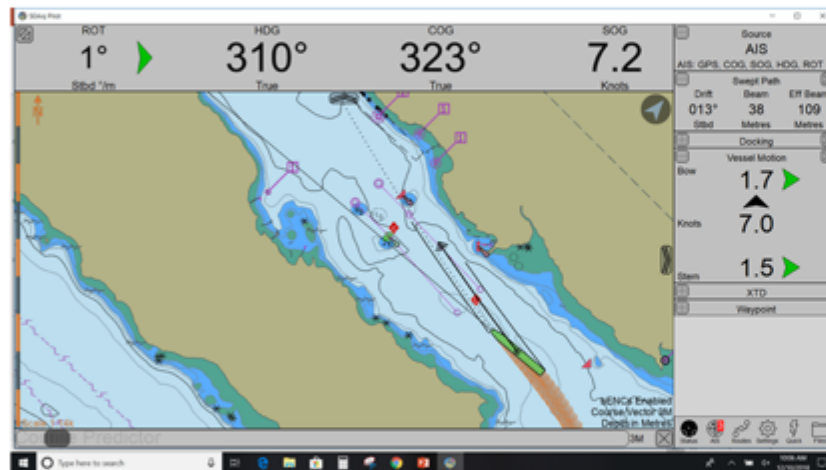
4th Run



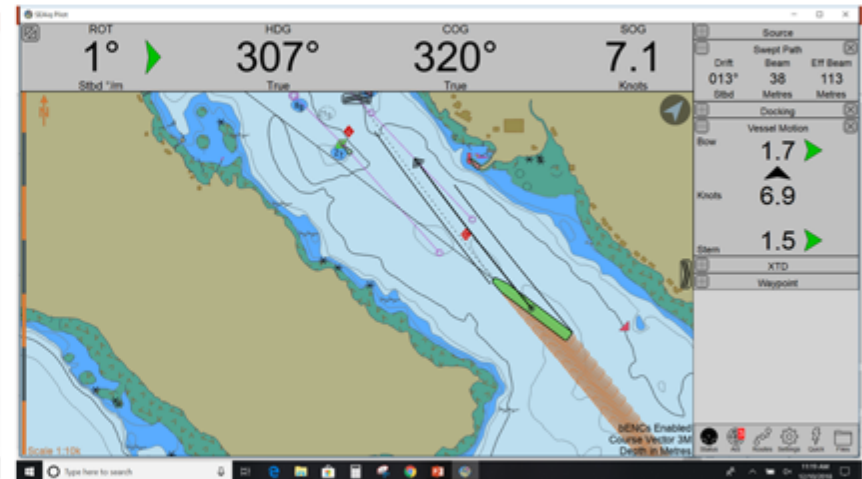


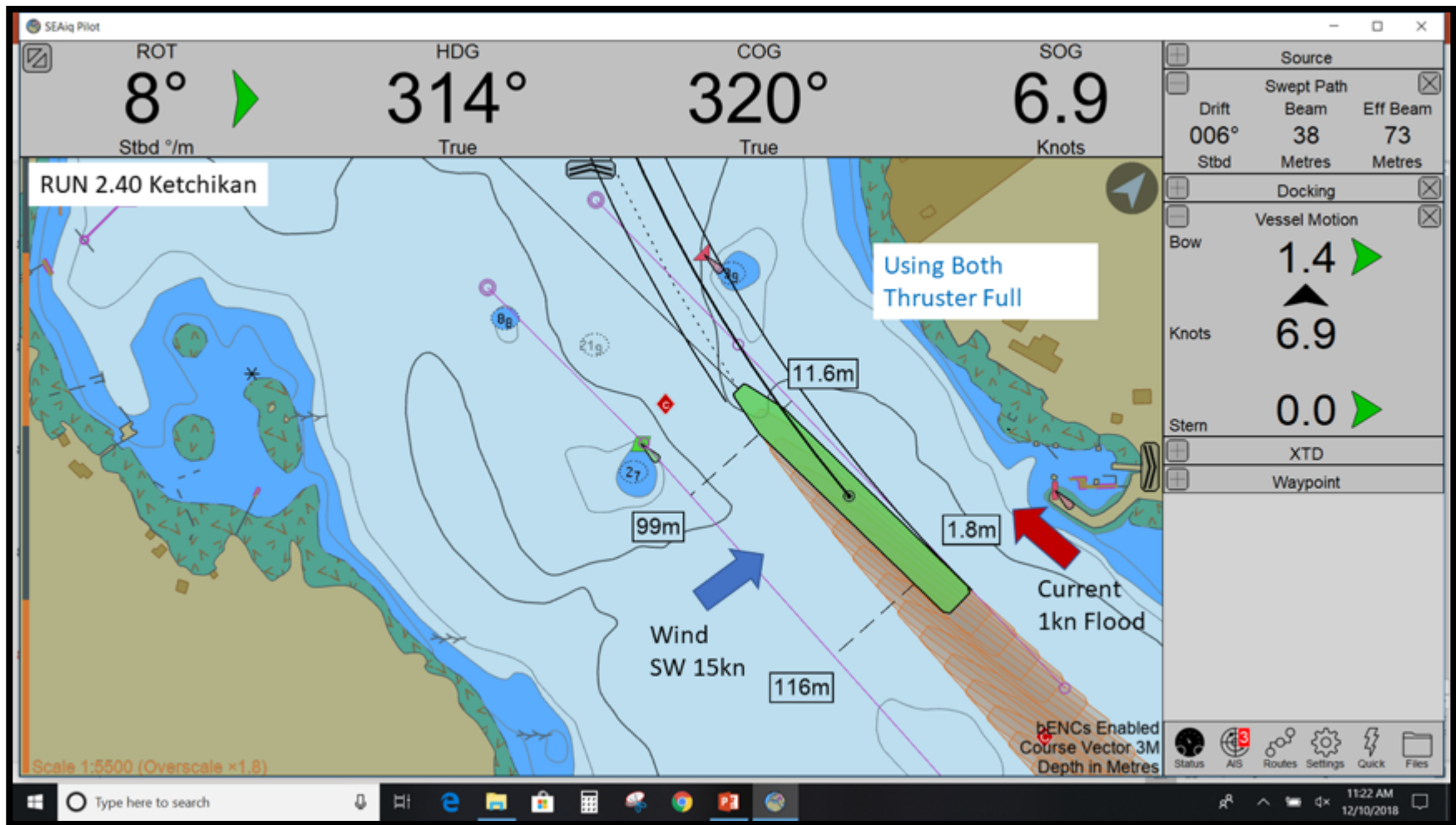
Same Conditions, Different Pilot

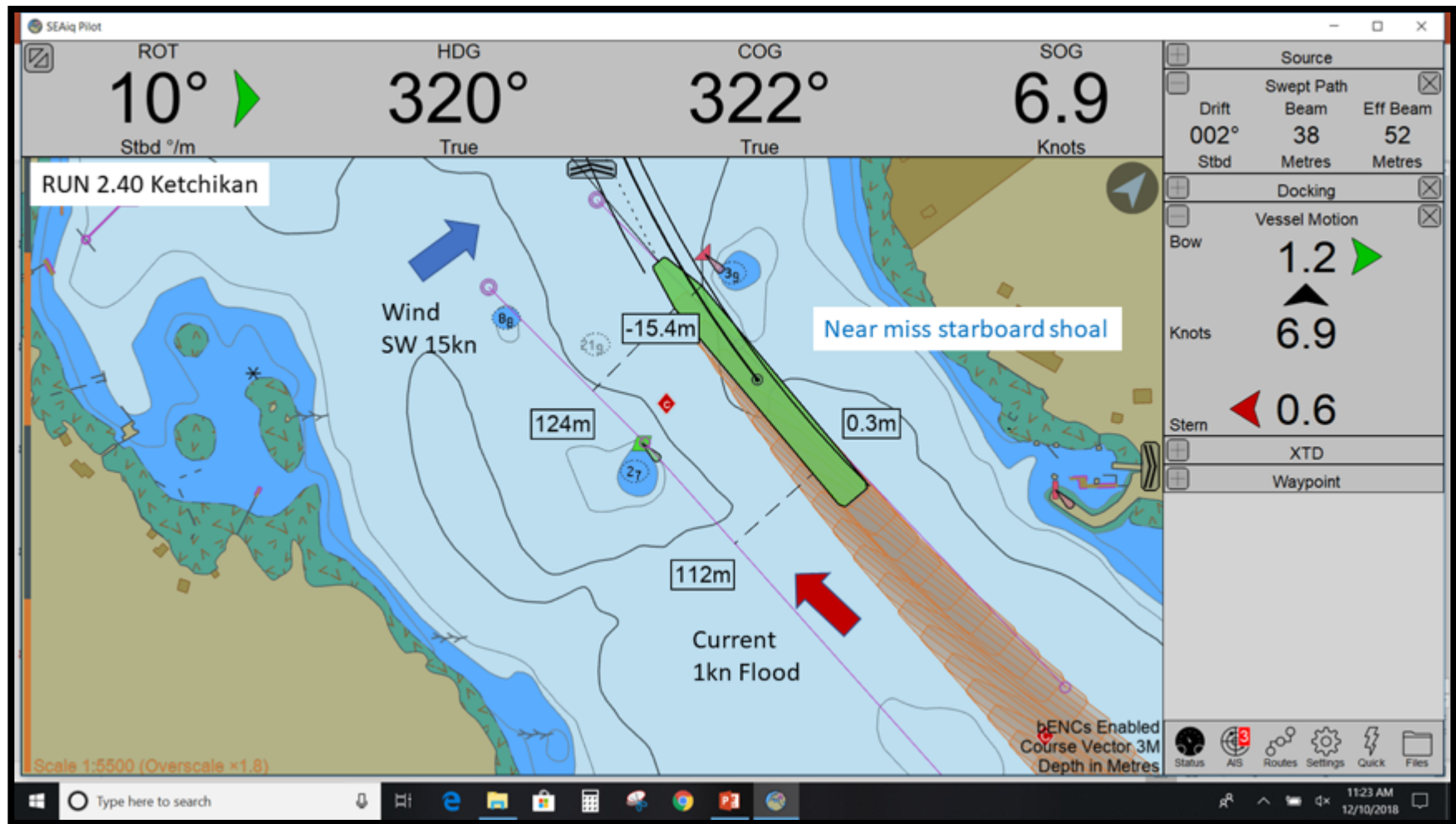
Run 2.39

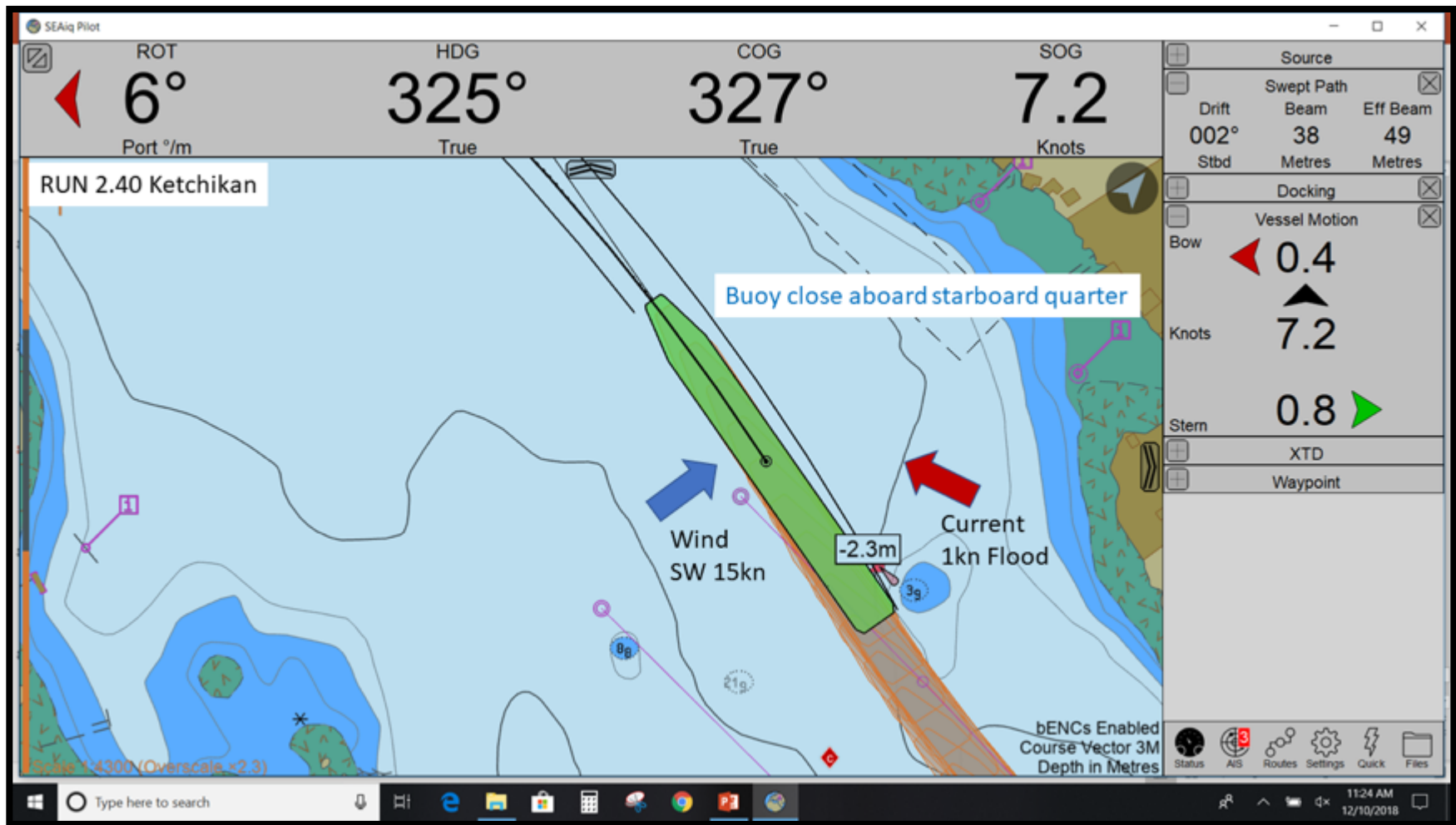


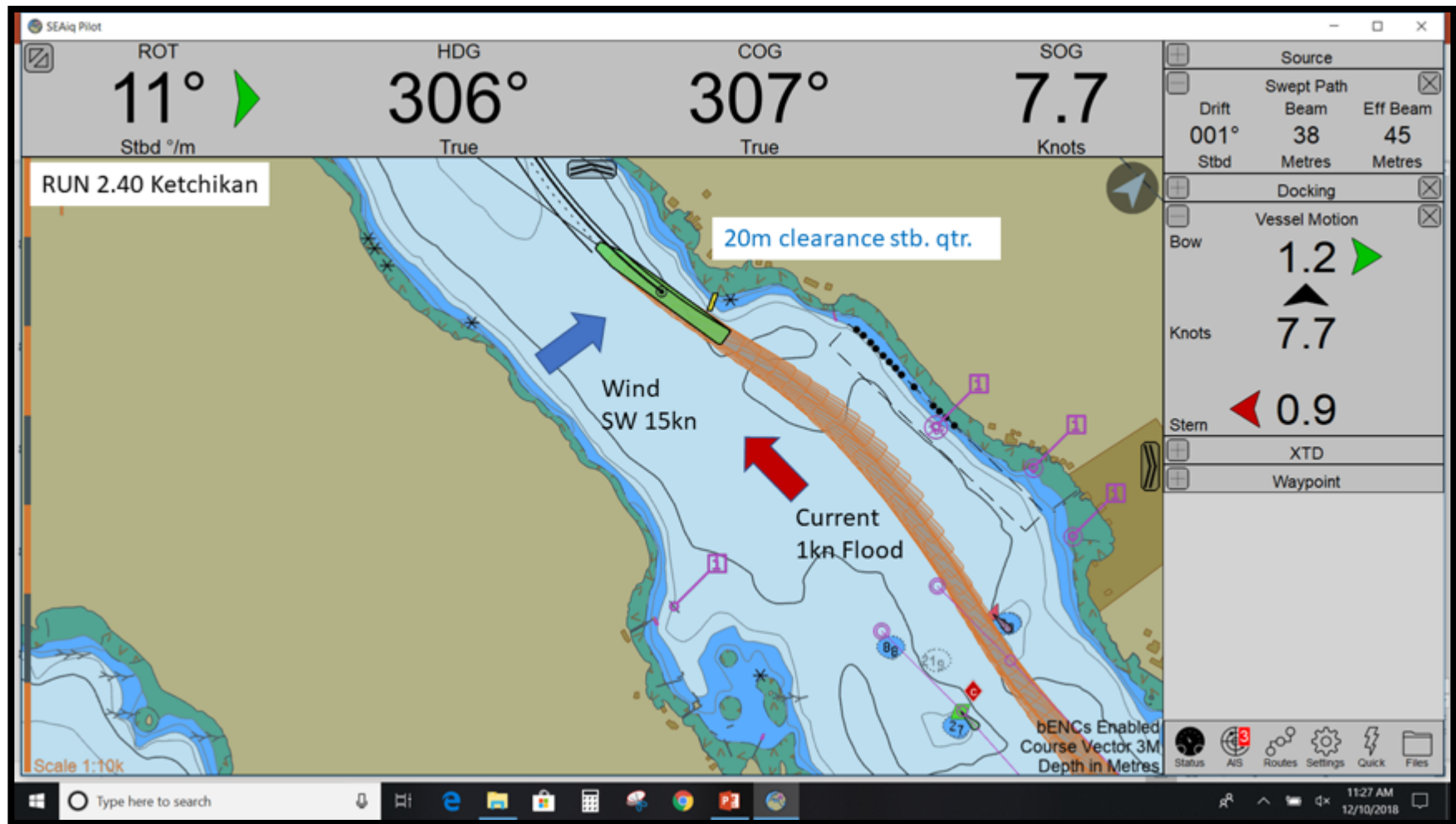
Run 2.4

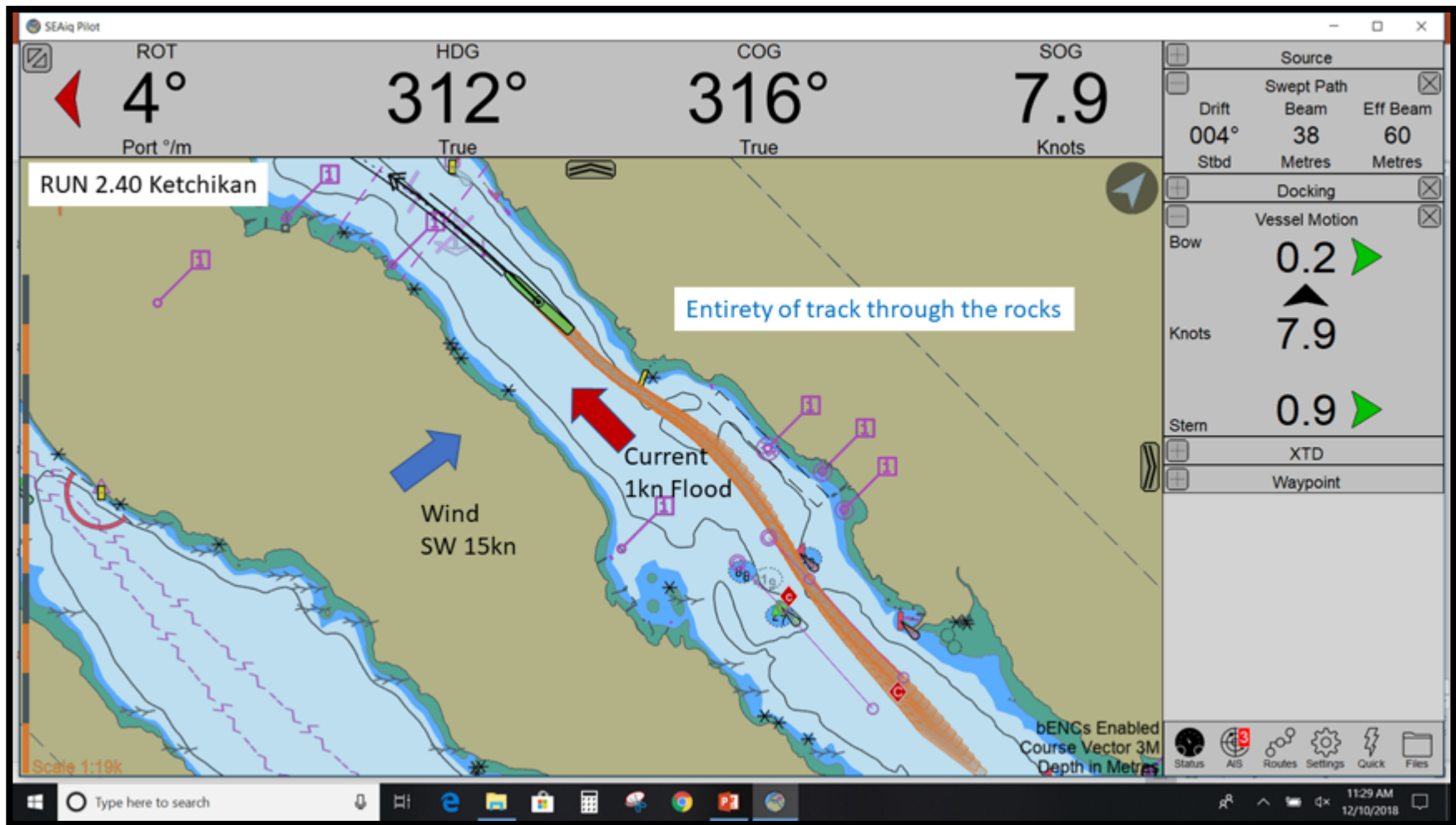


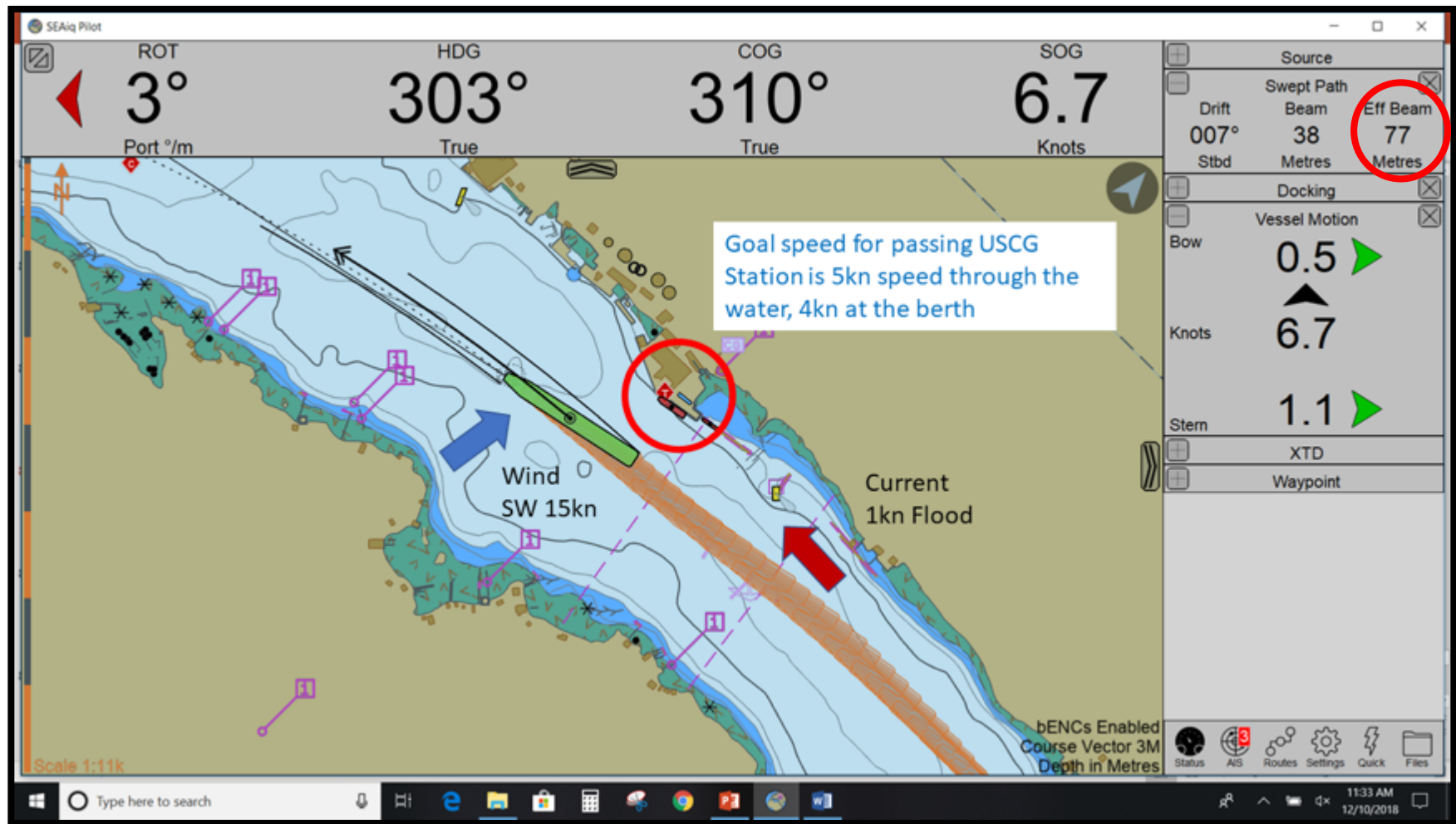








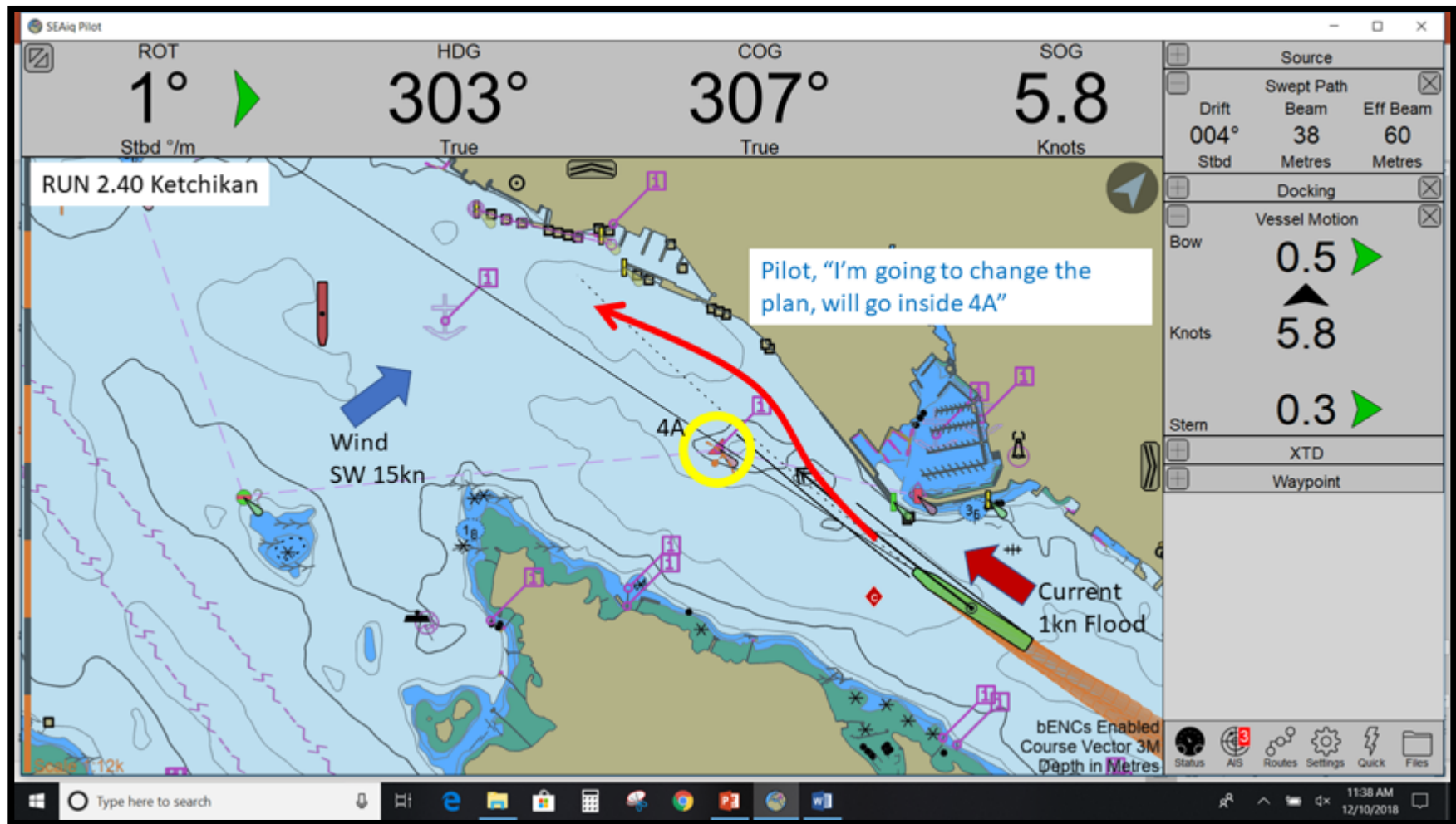


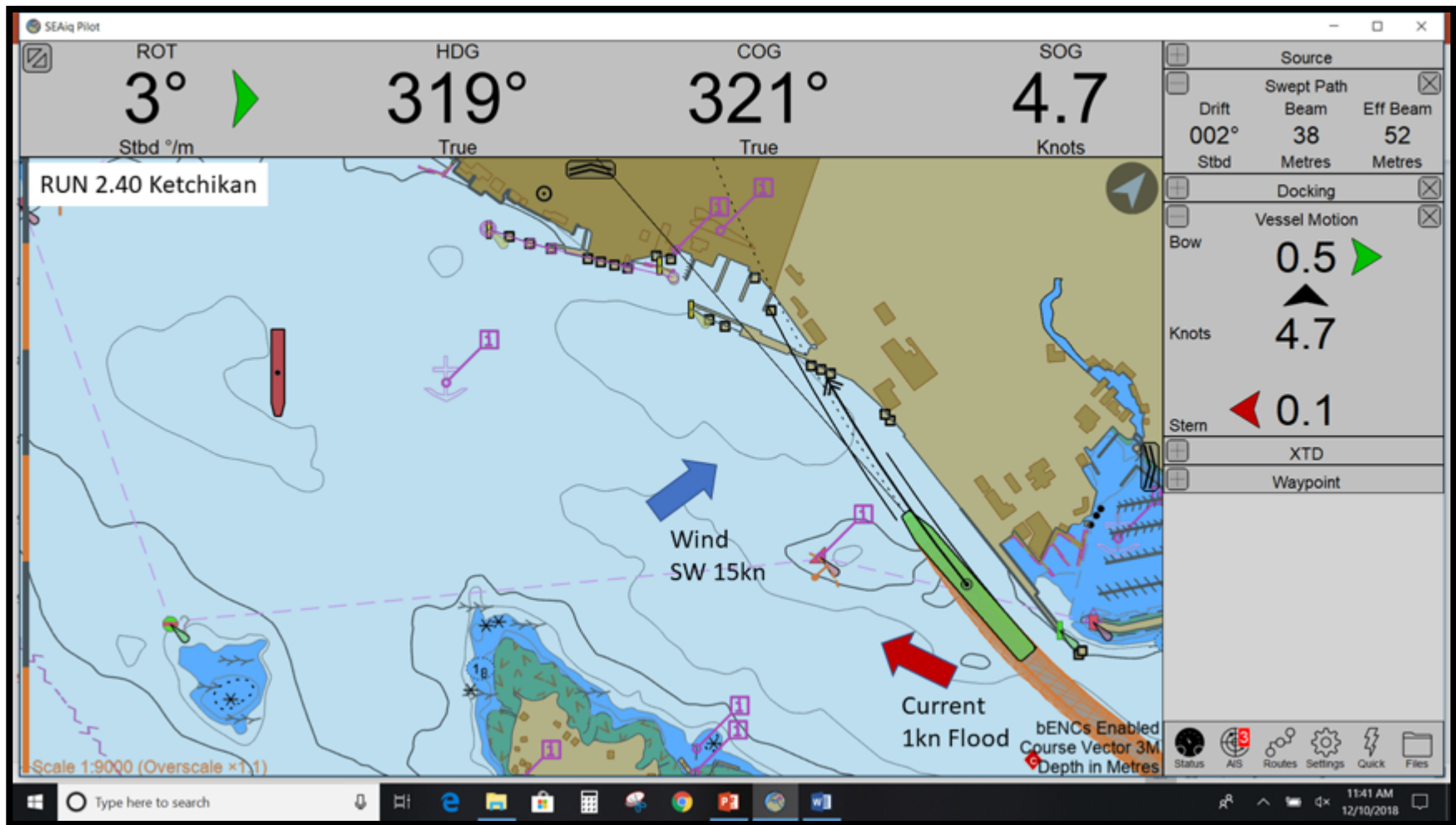


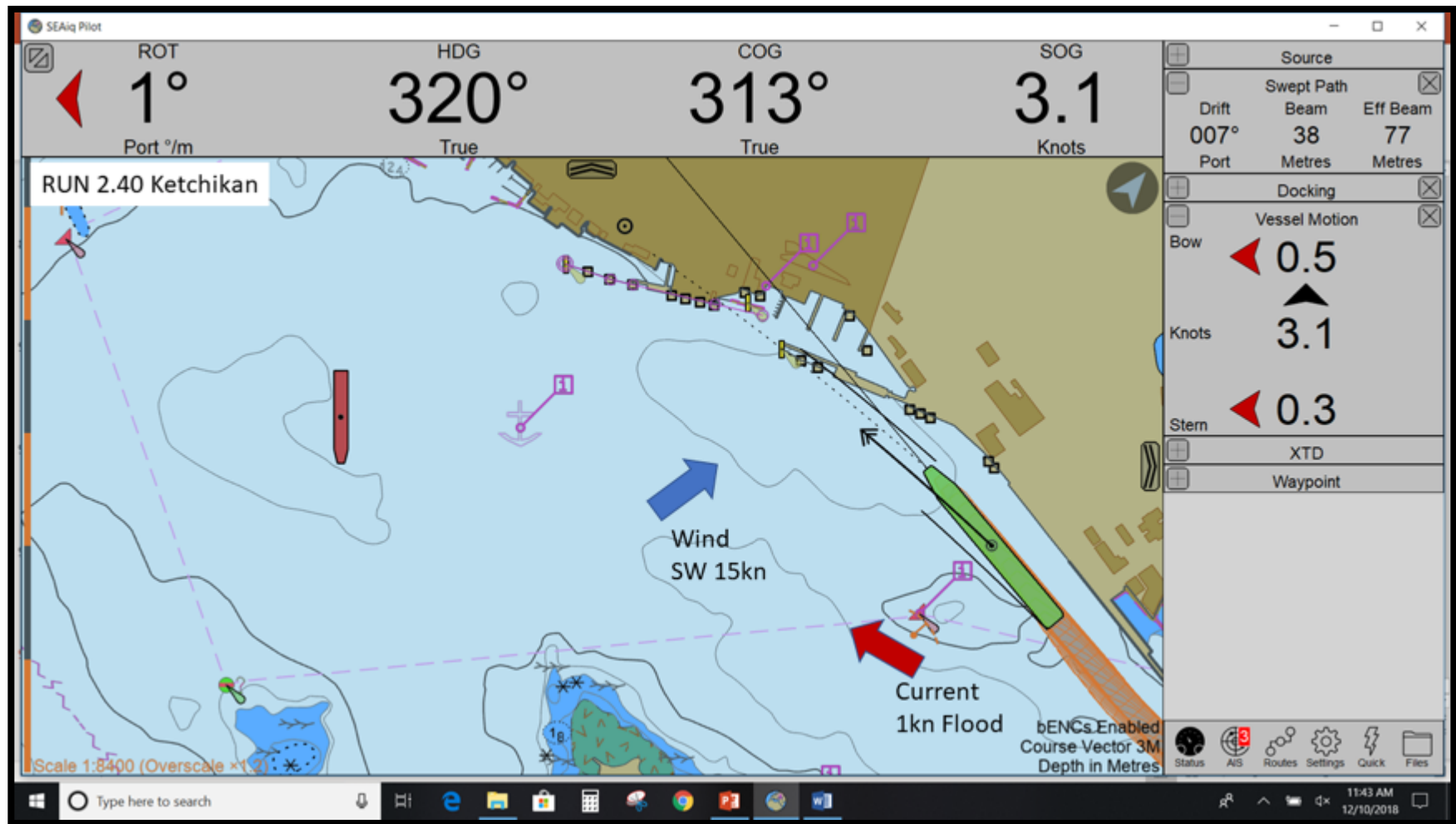


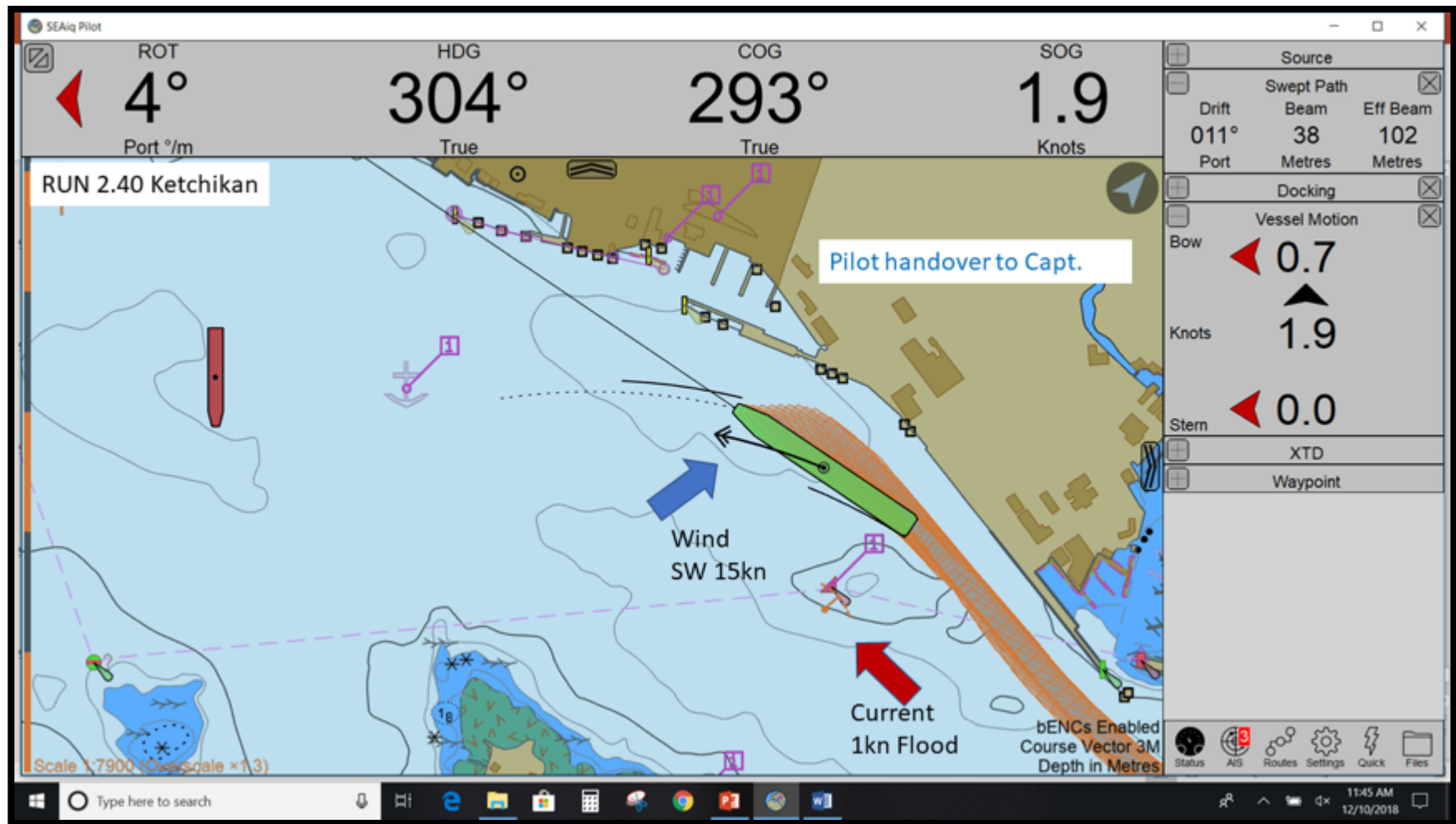
RUN 2.40

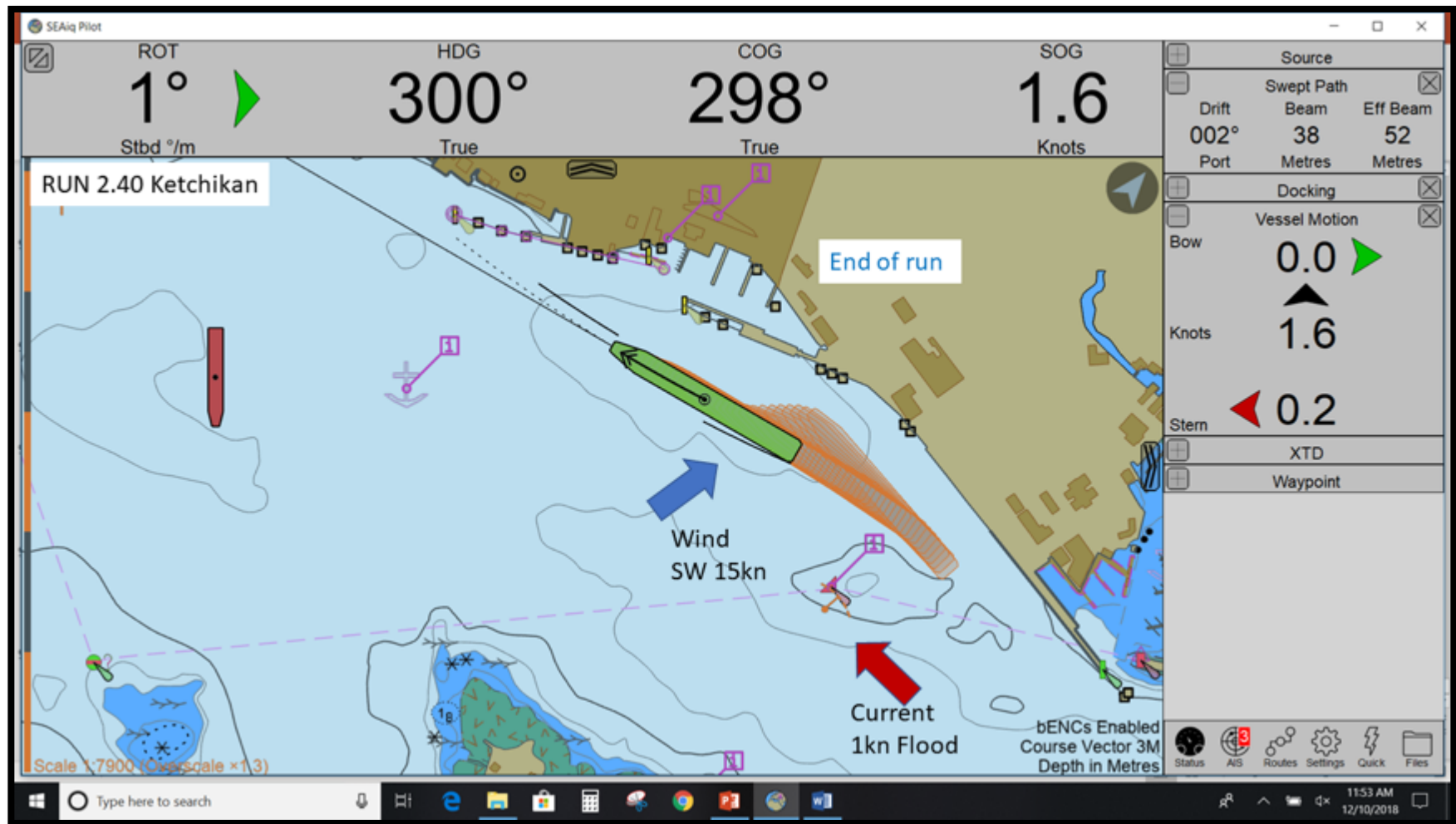










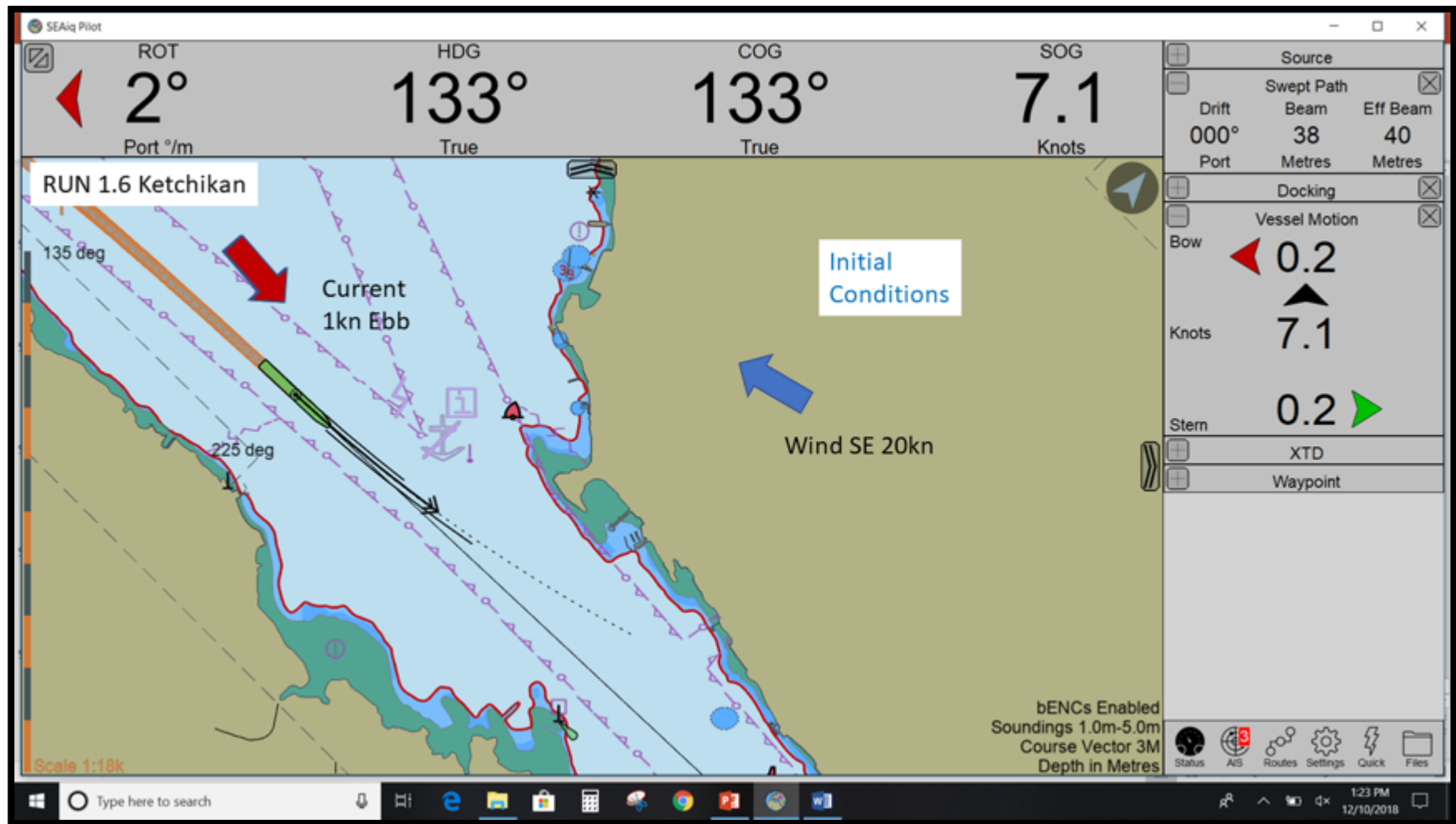


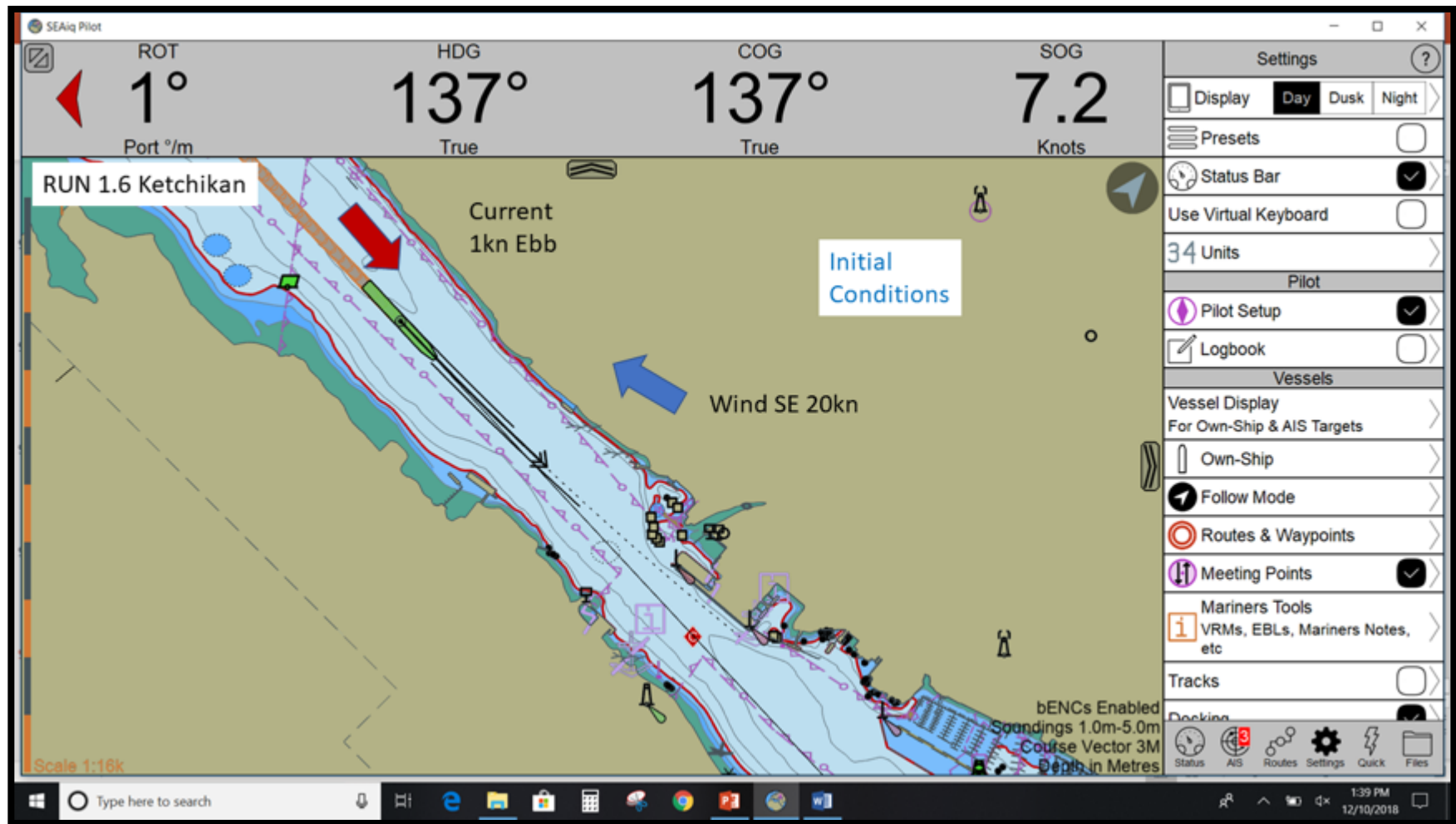
Run 1.6 Ketchikan, North Approach, SE20, 1kn Ebb

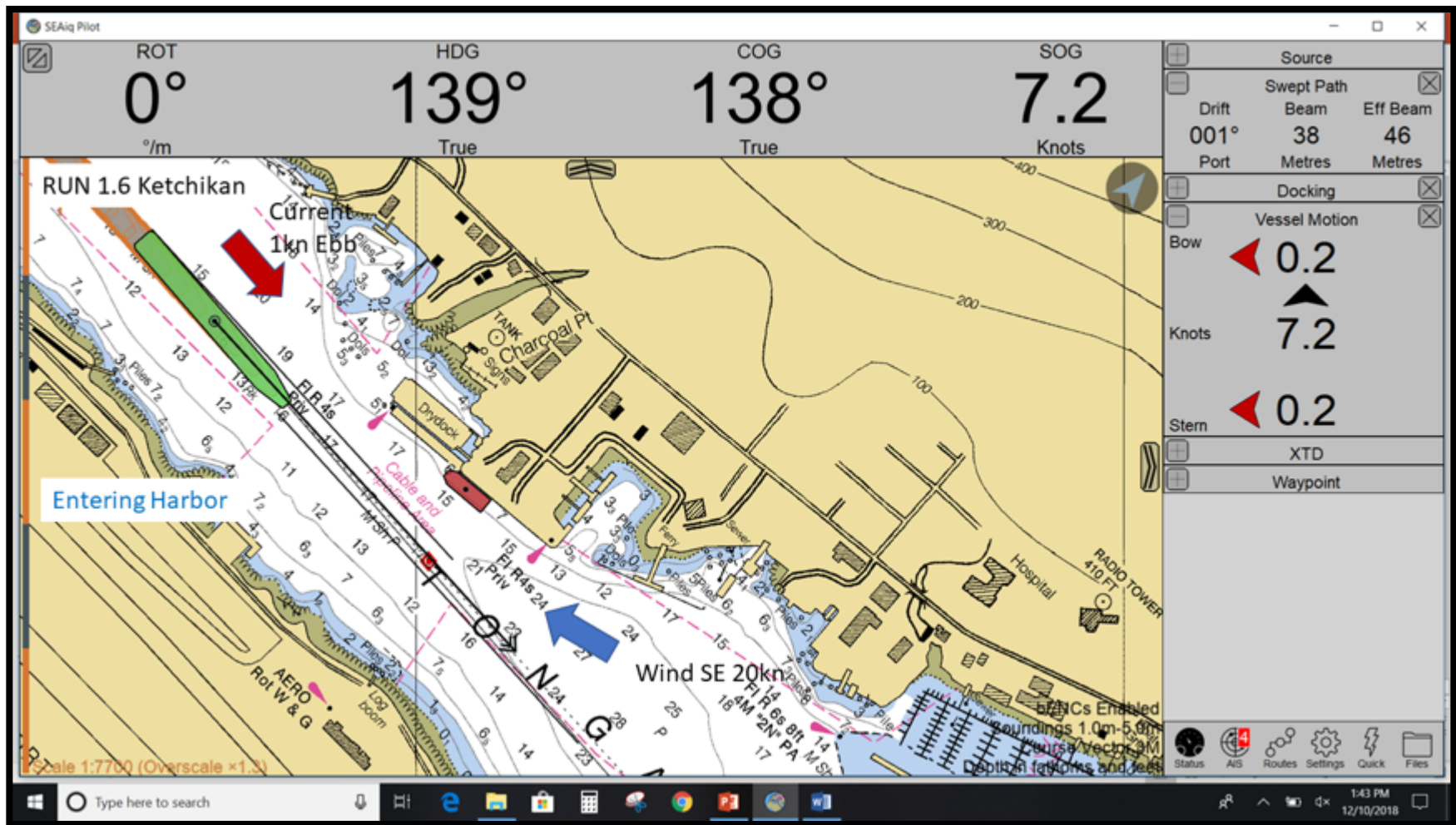
1.6 SE20 1kn Ebb, North Approach to Ketchikan

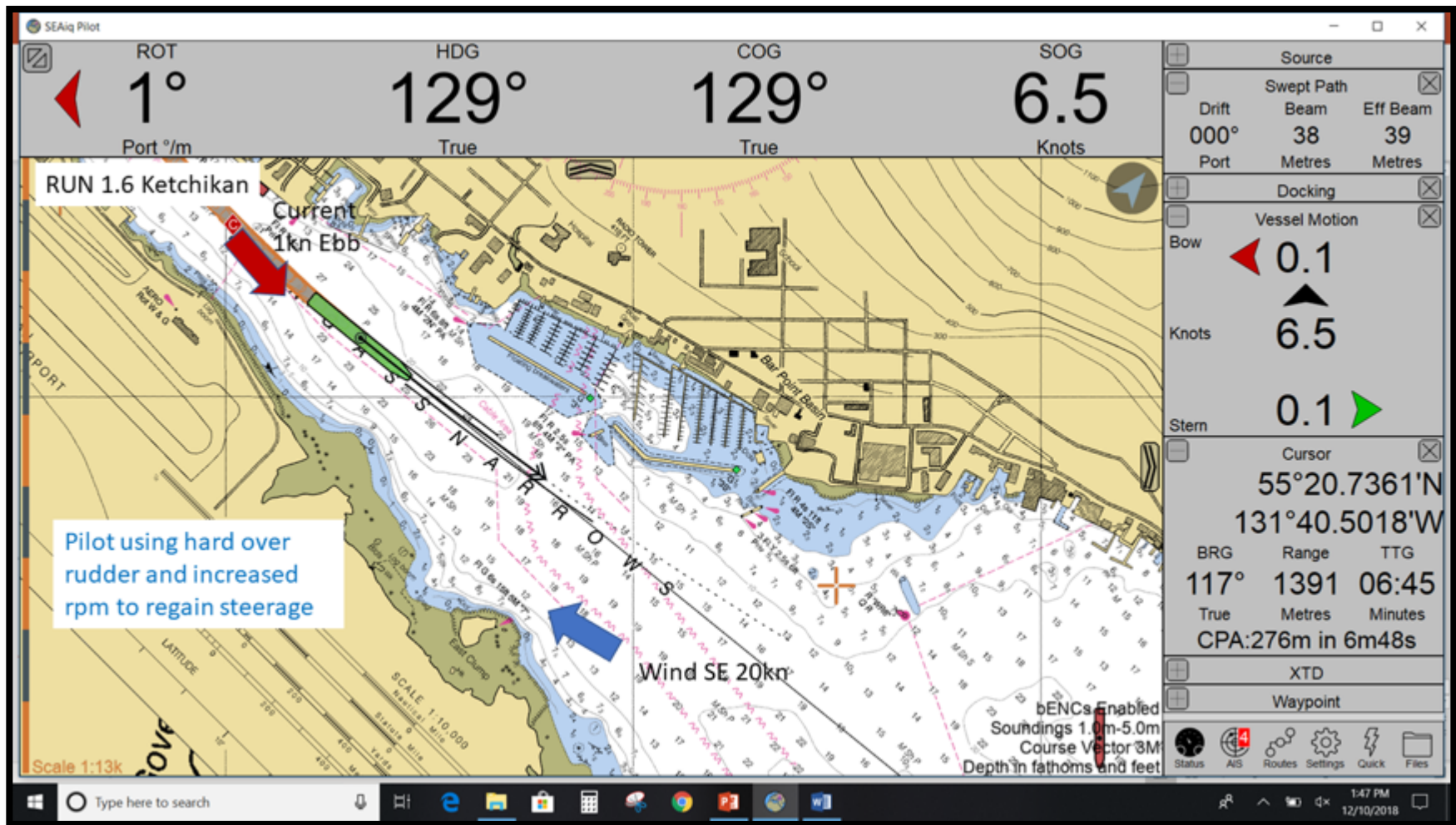
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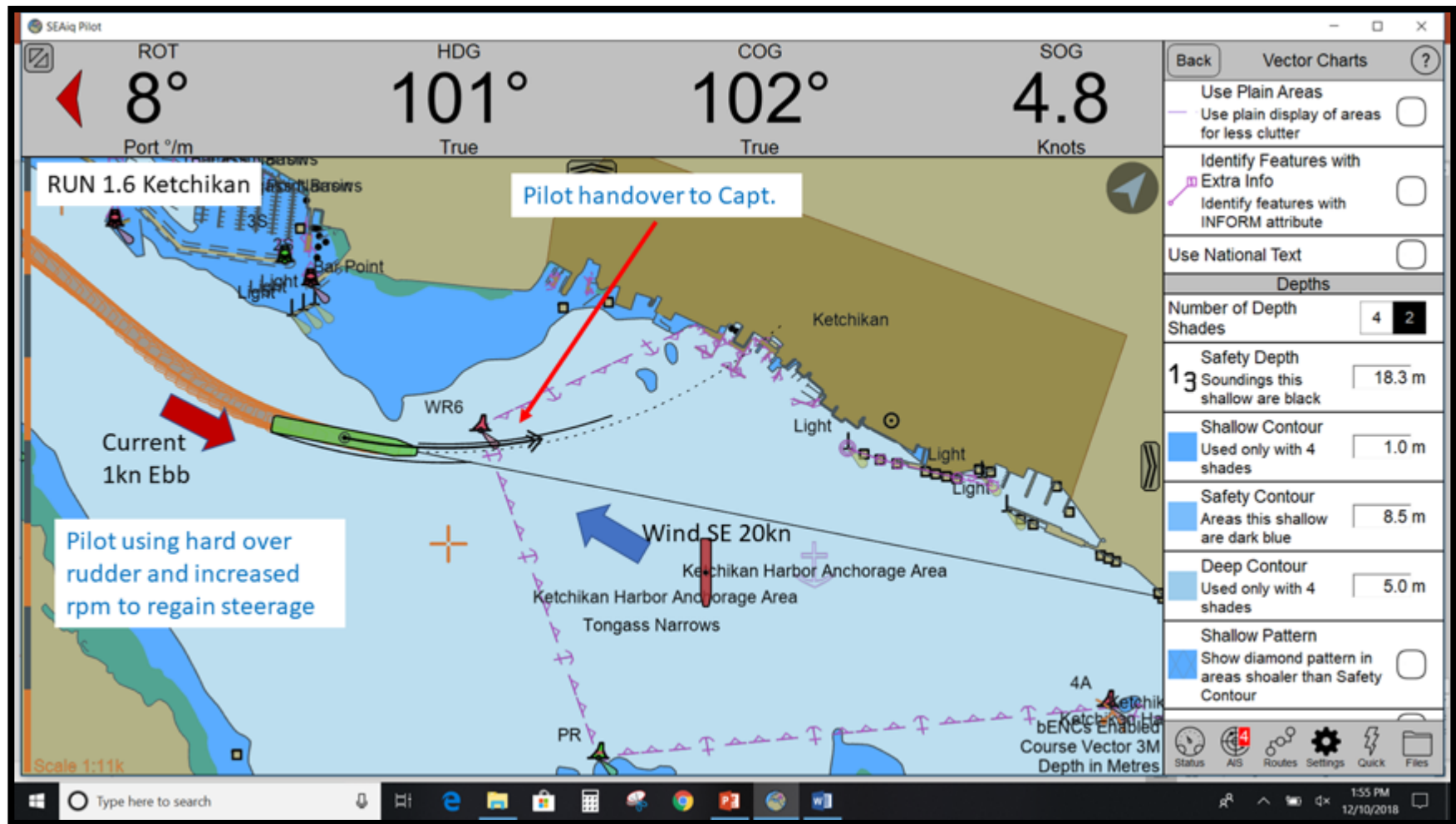
5th Run, 1st run after lunch

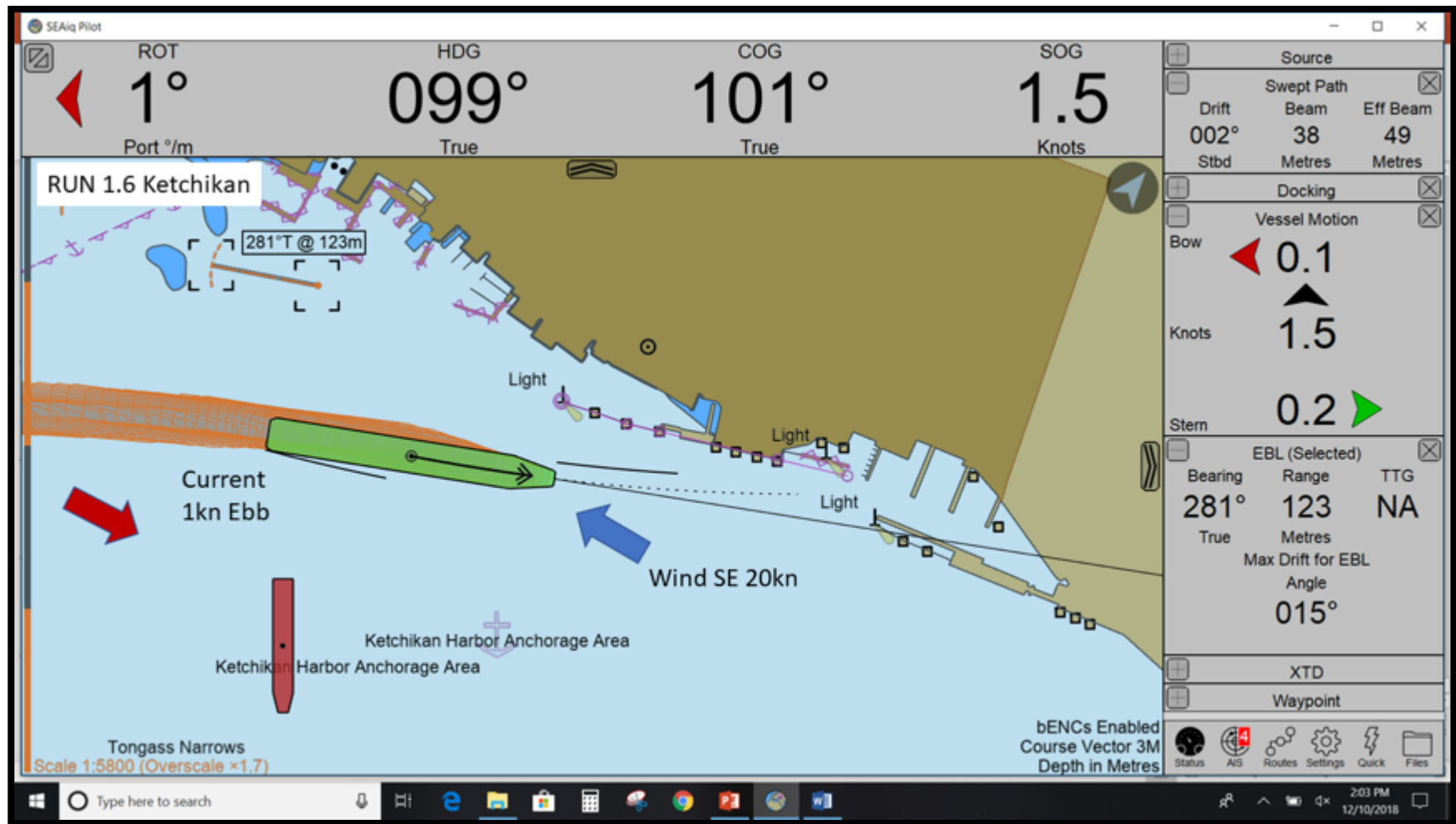












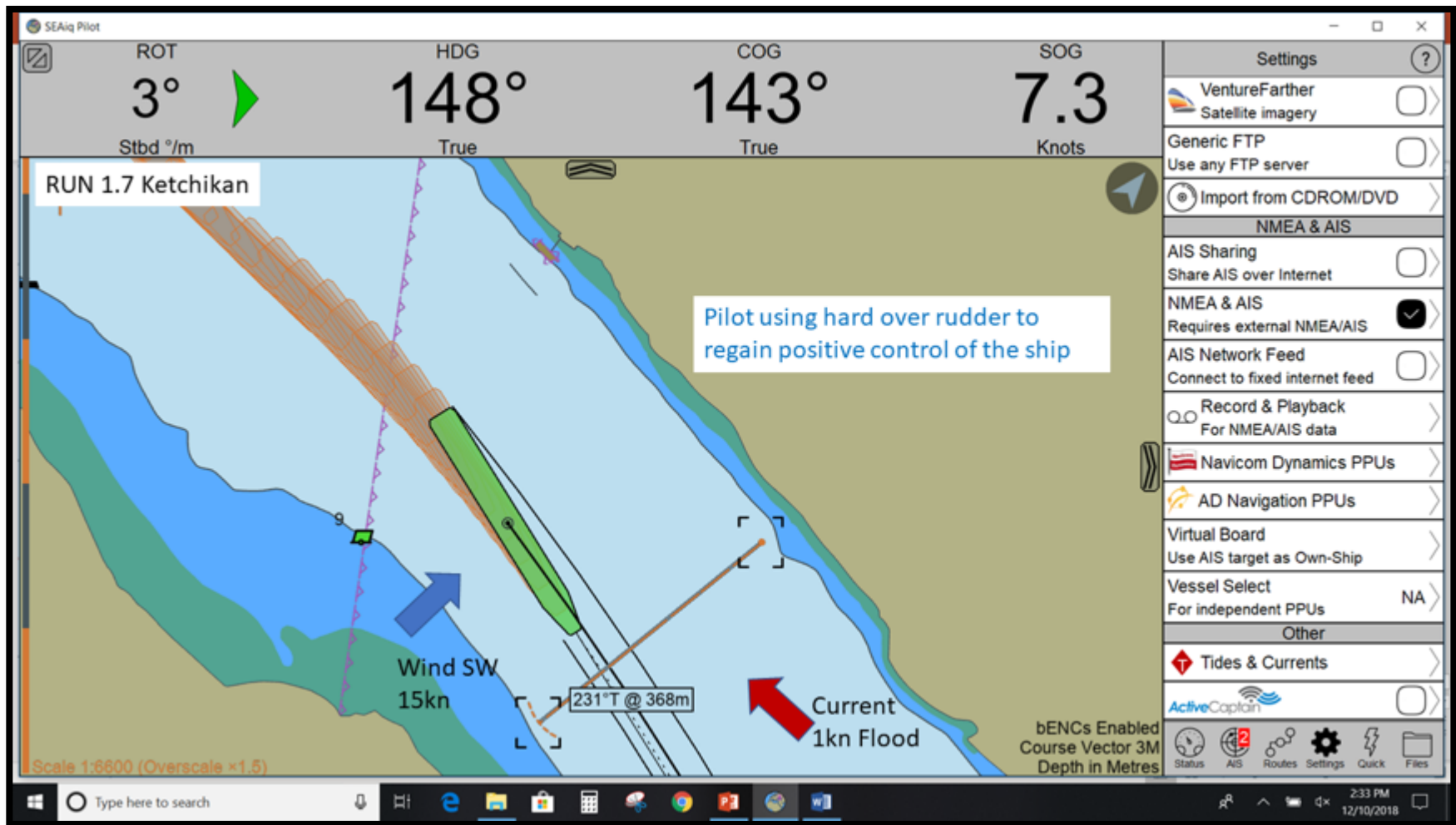
Run 1.7 Ketchikan, North Approach, SW20kn, 1kn Flood

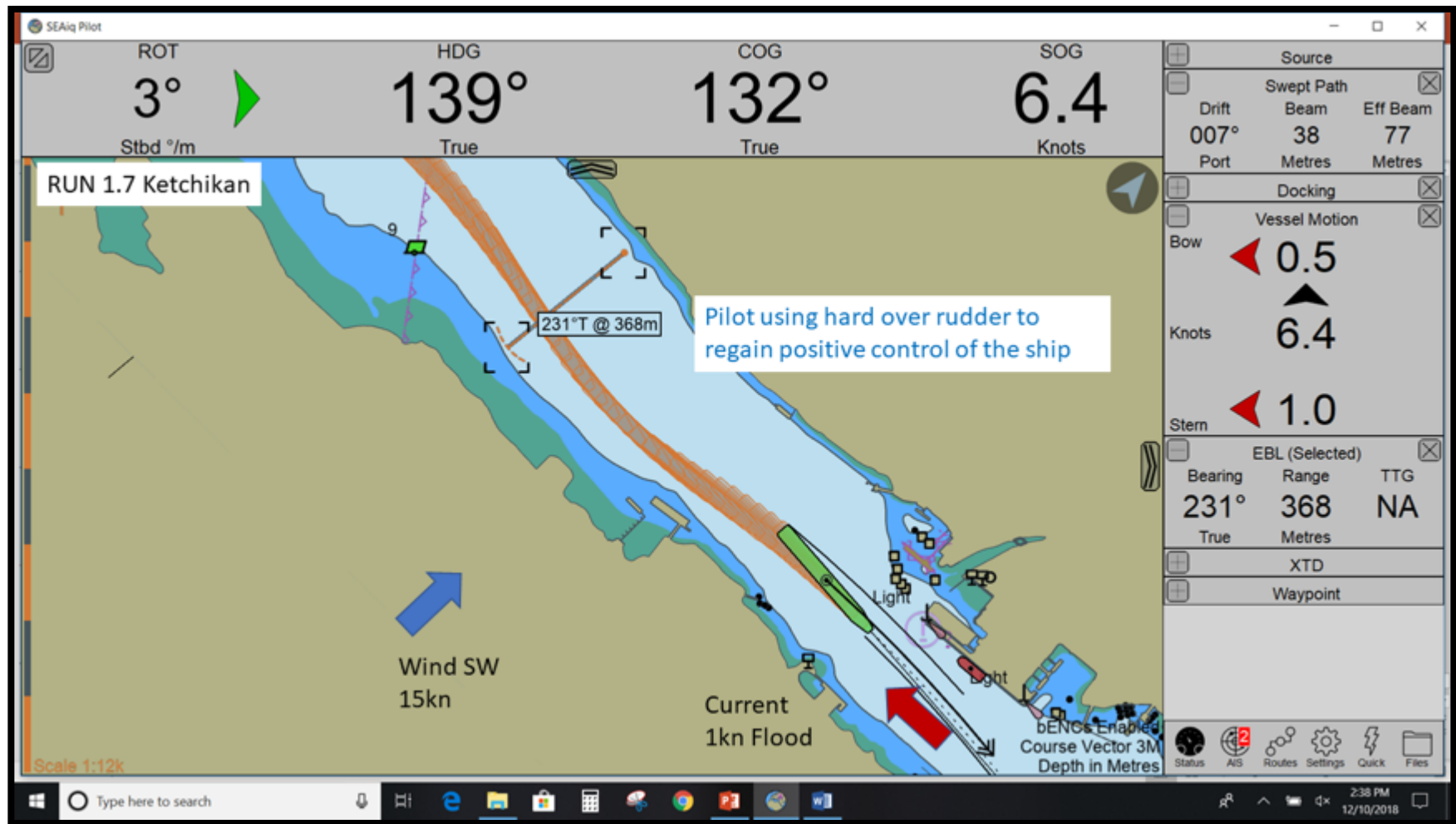
1.7 SW15 1kn Flood, North Approach to Ketchikan

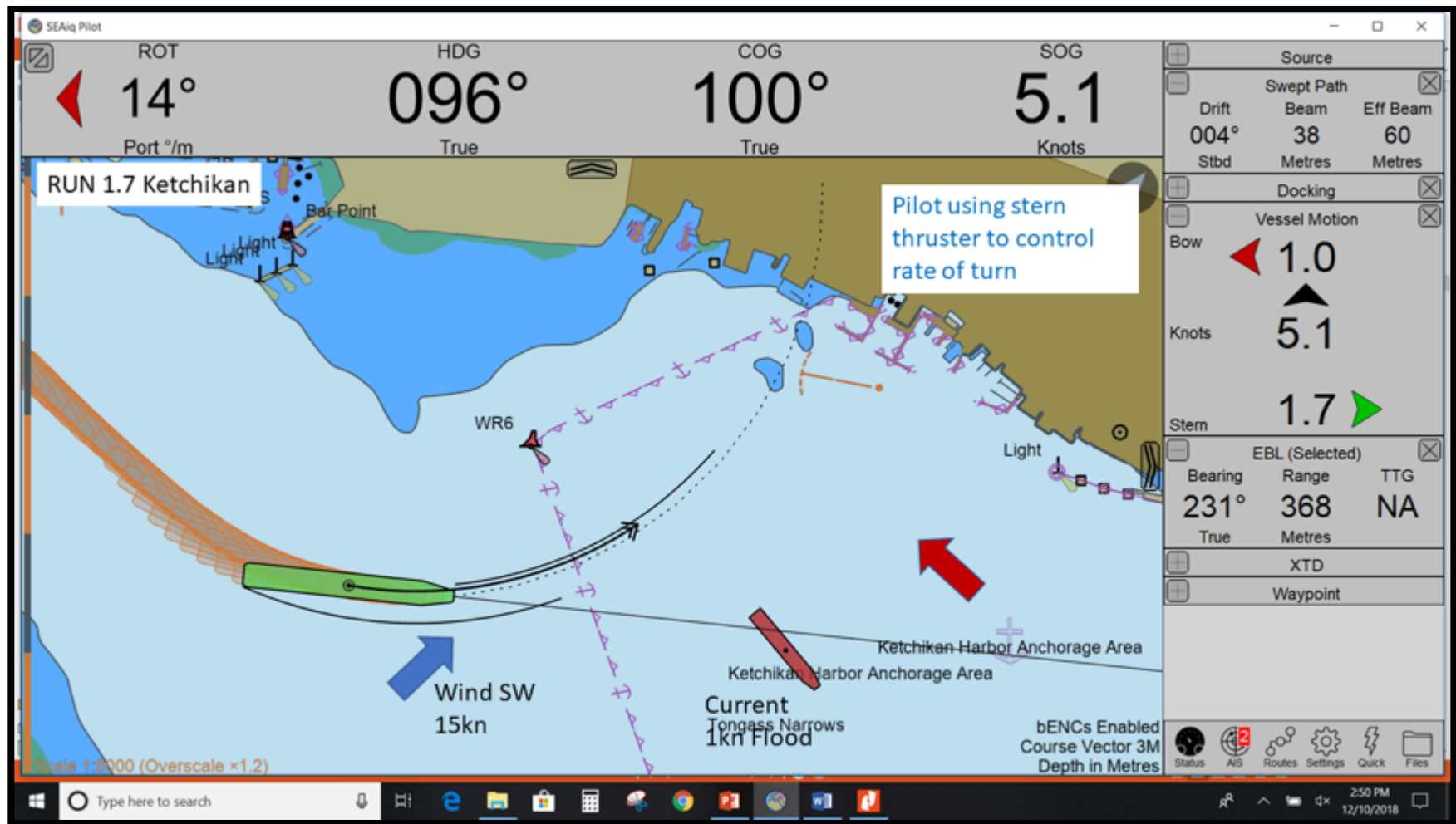
(Run not counted due to sim anomaly)

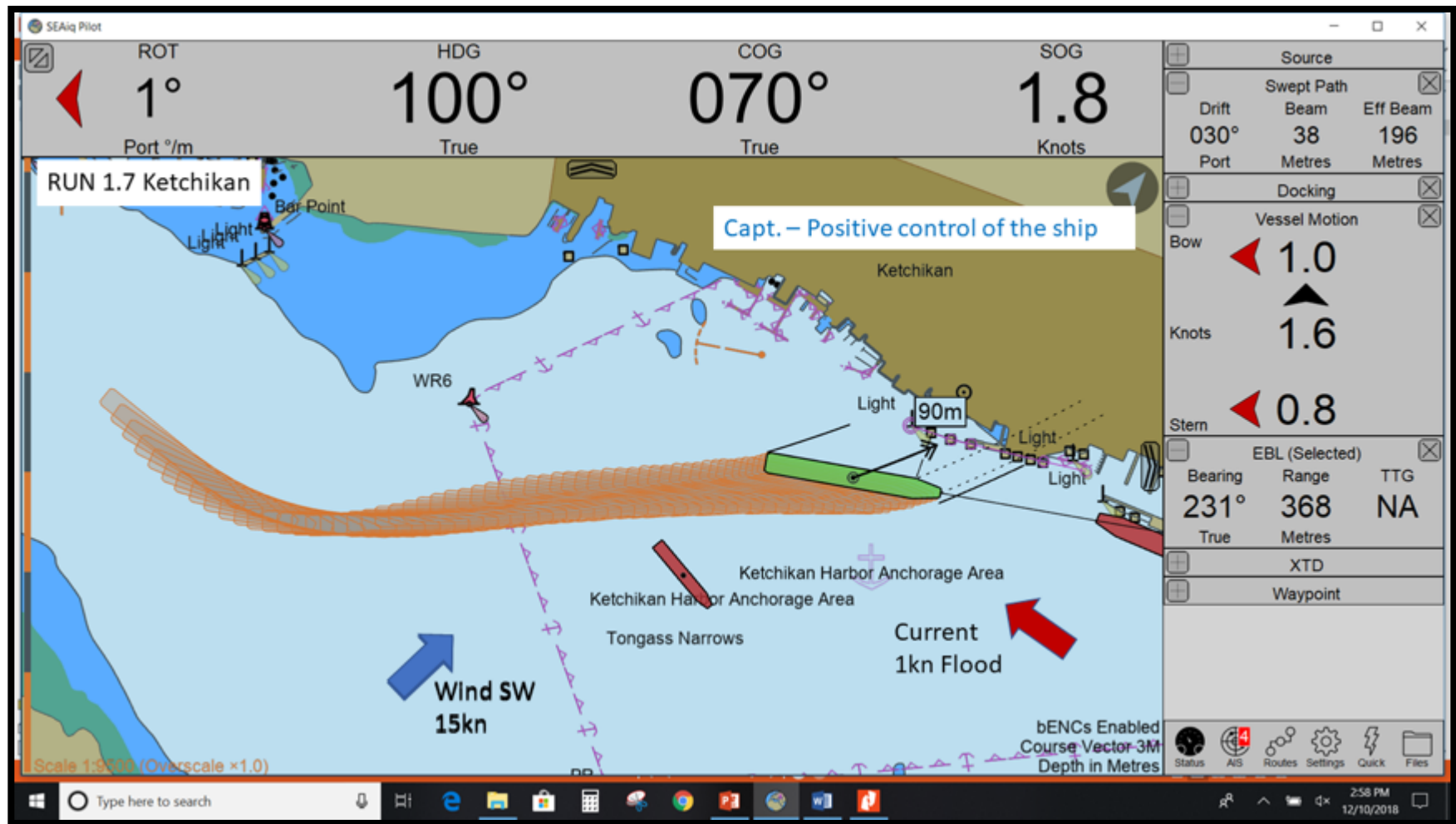
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6th Run







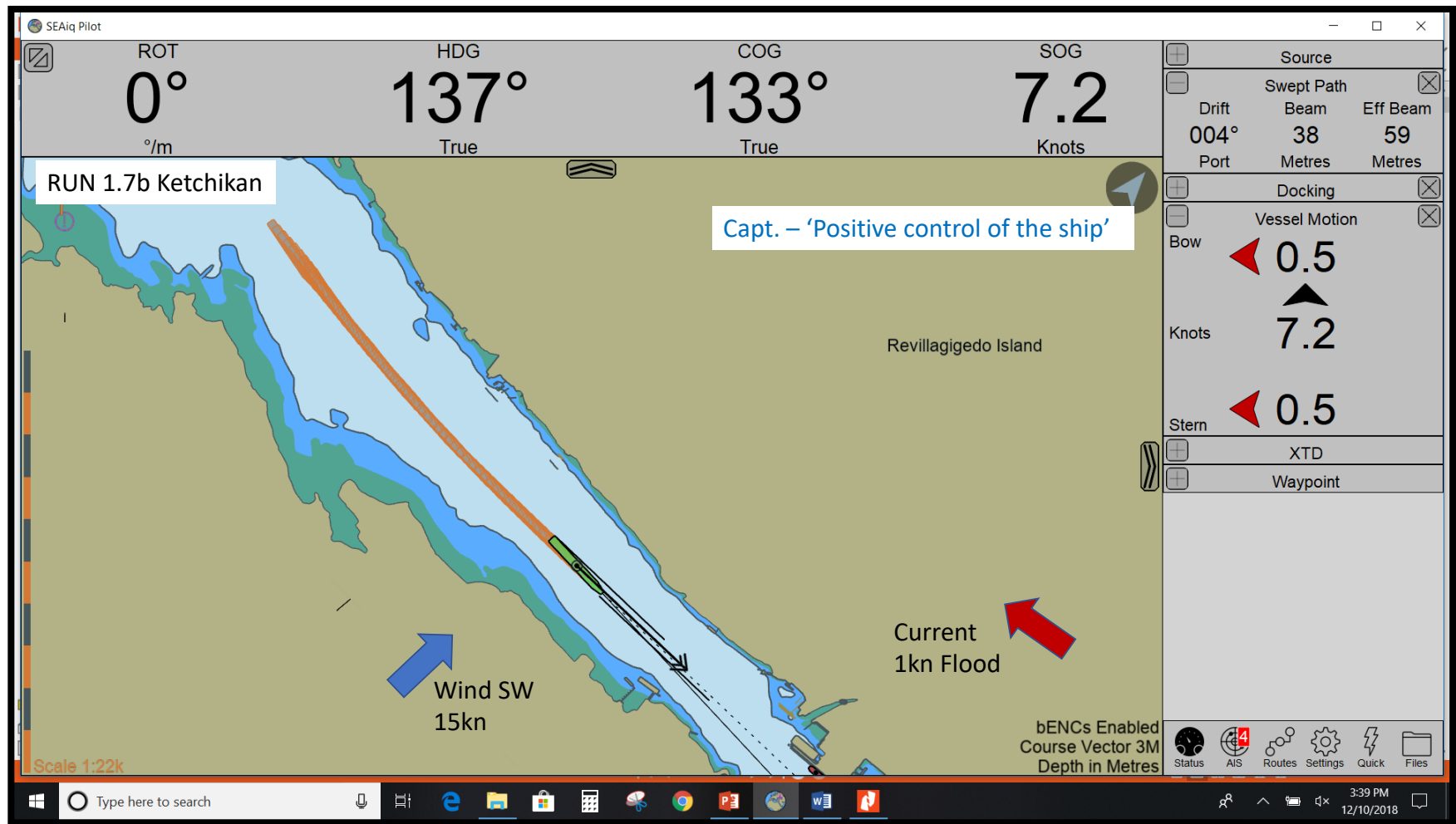


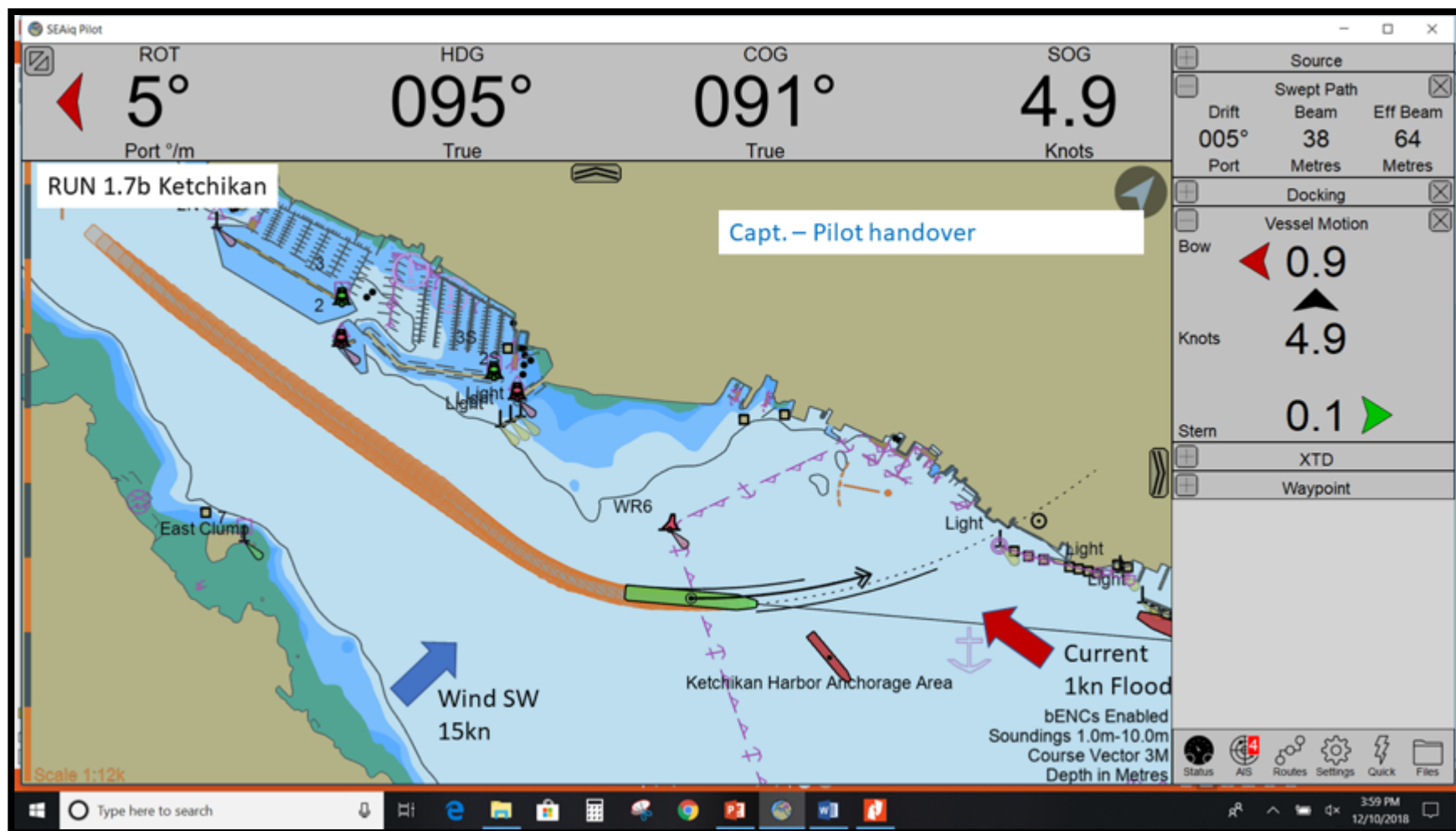
Run 1.7B Ketchikan, North Approach, SW15, 1kn Flood

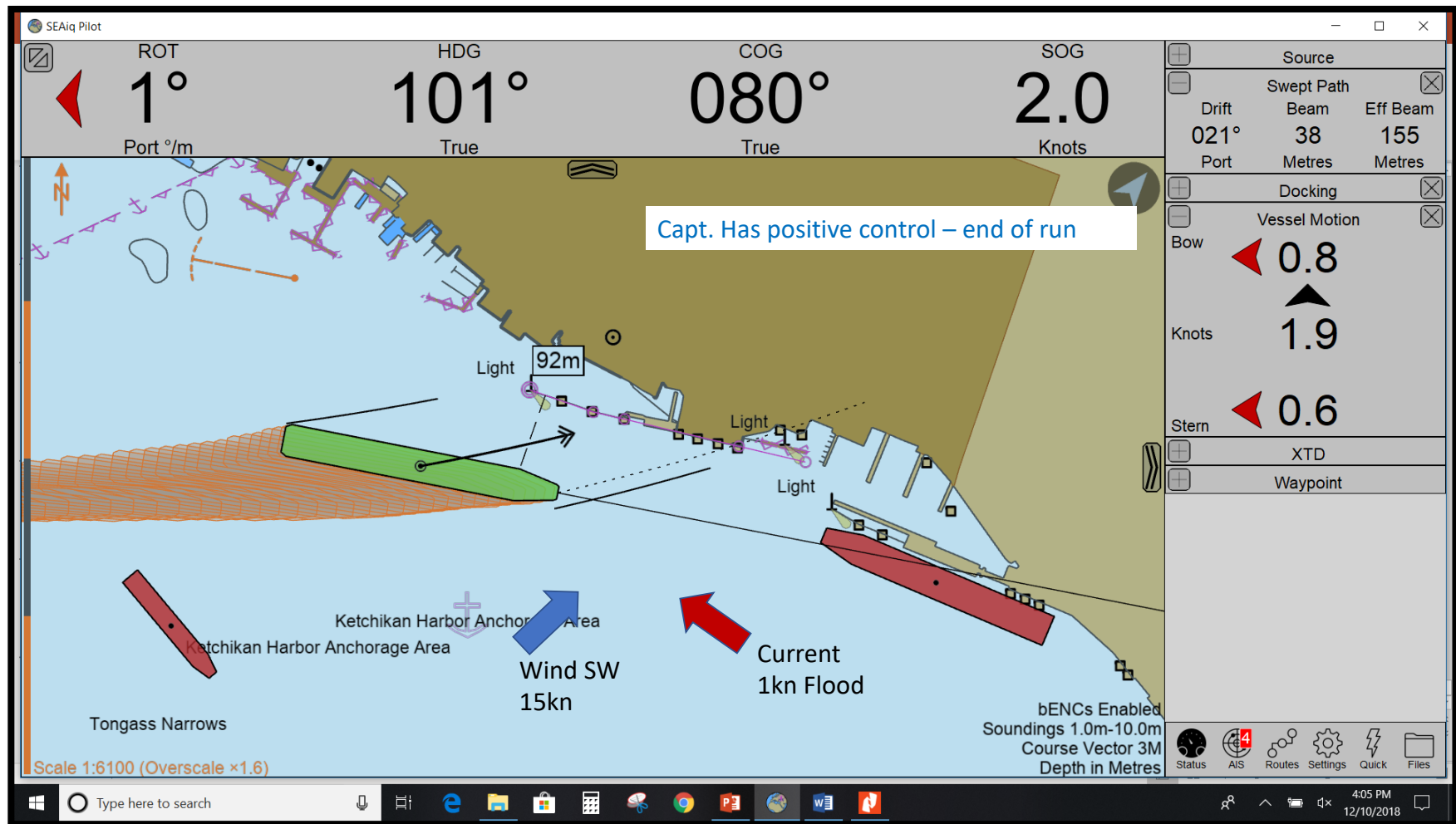
1.7b SW15 1kn Flood, North Approach to Ketchikan

Monday 12/10/2018

6th Run





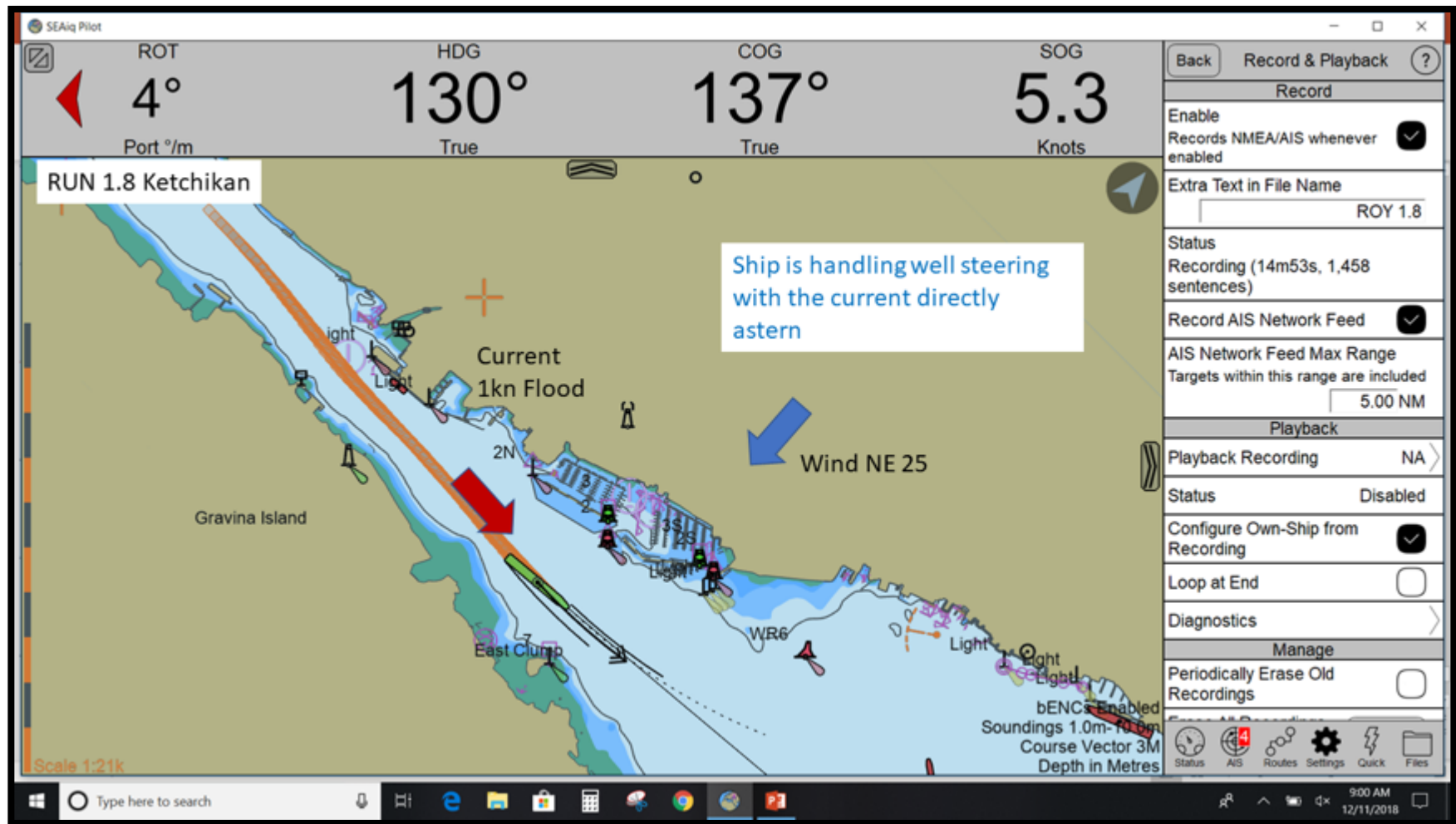


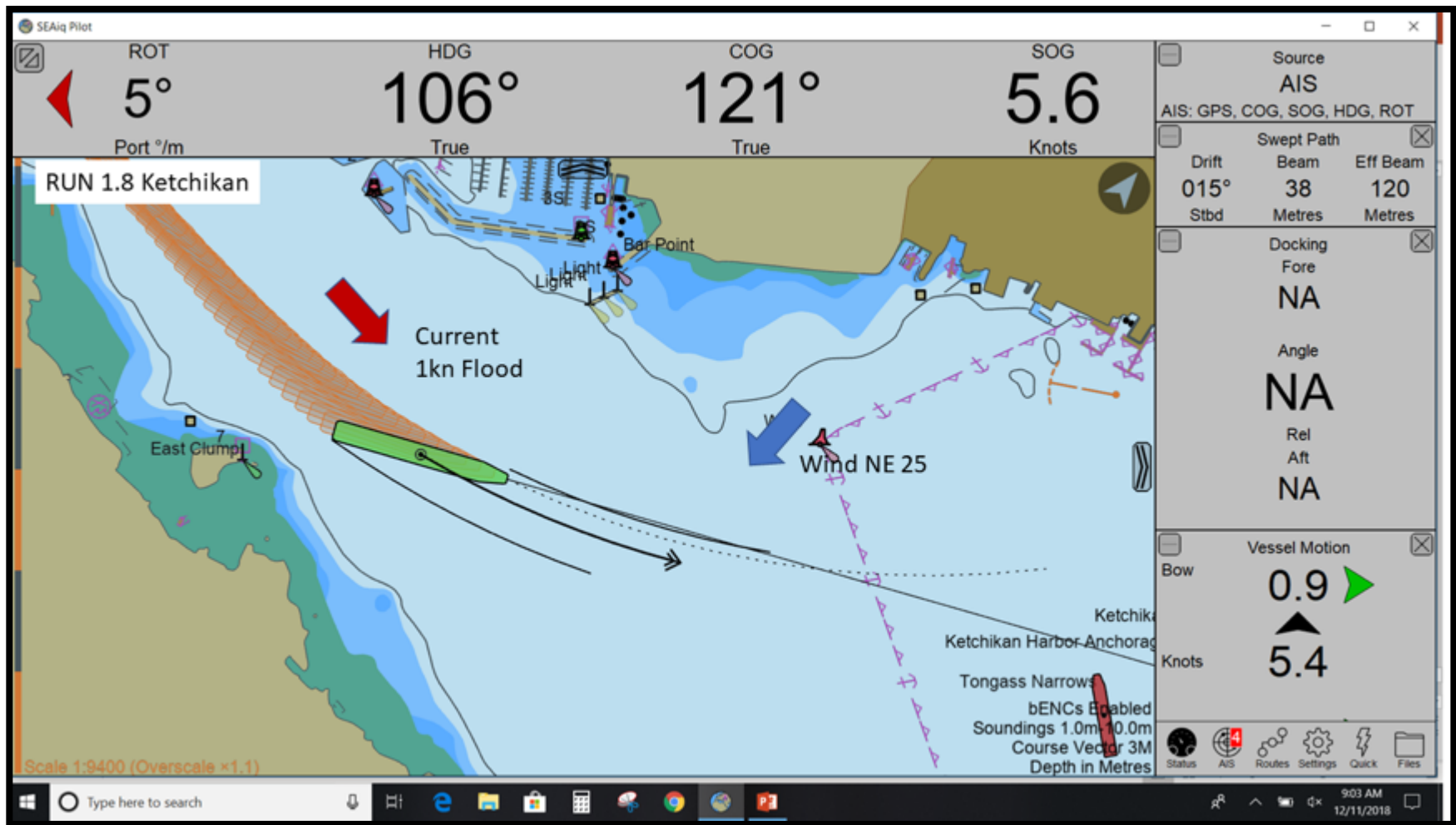
Run 1.8 Ketchikan, North Approach, SE25kn, 1kn Ebb

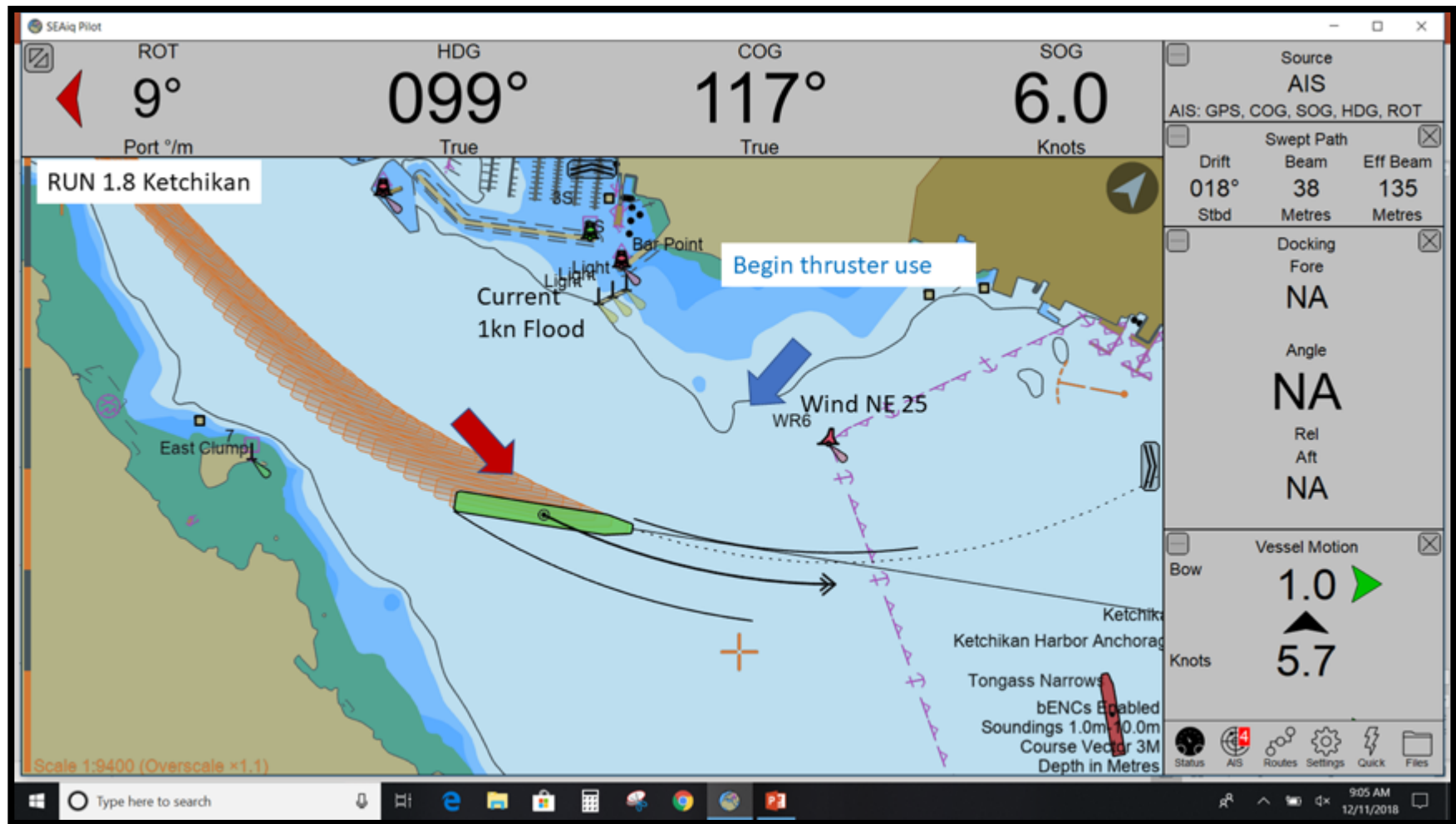
1.8 NE25 1kn Ebb, North Approach to Ketchikan

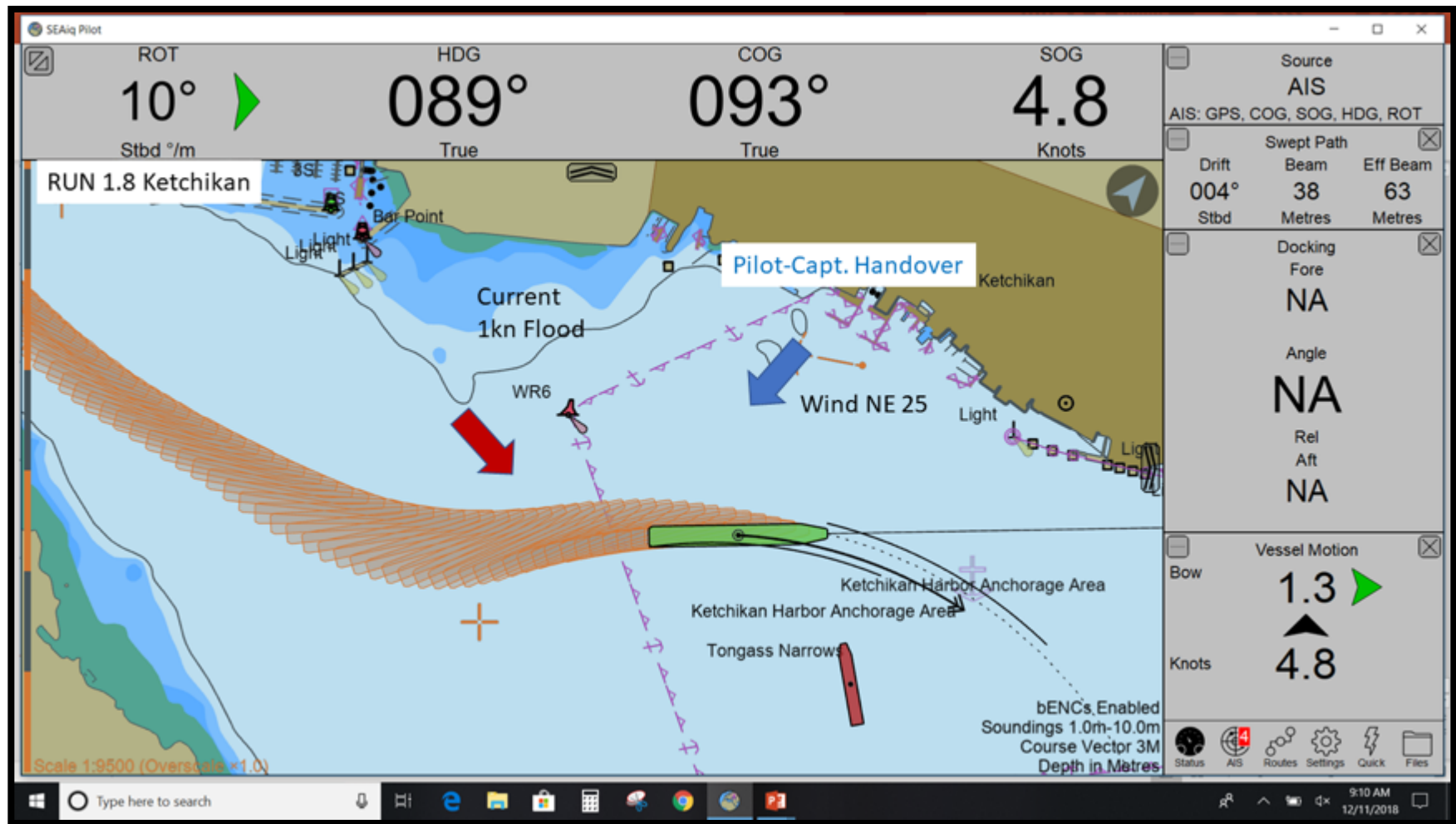
Tuesday 12/11/2018

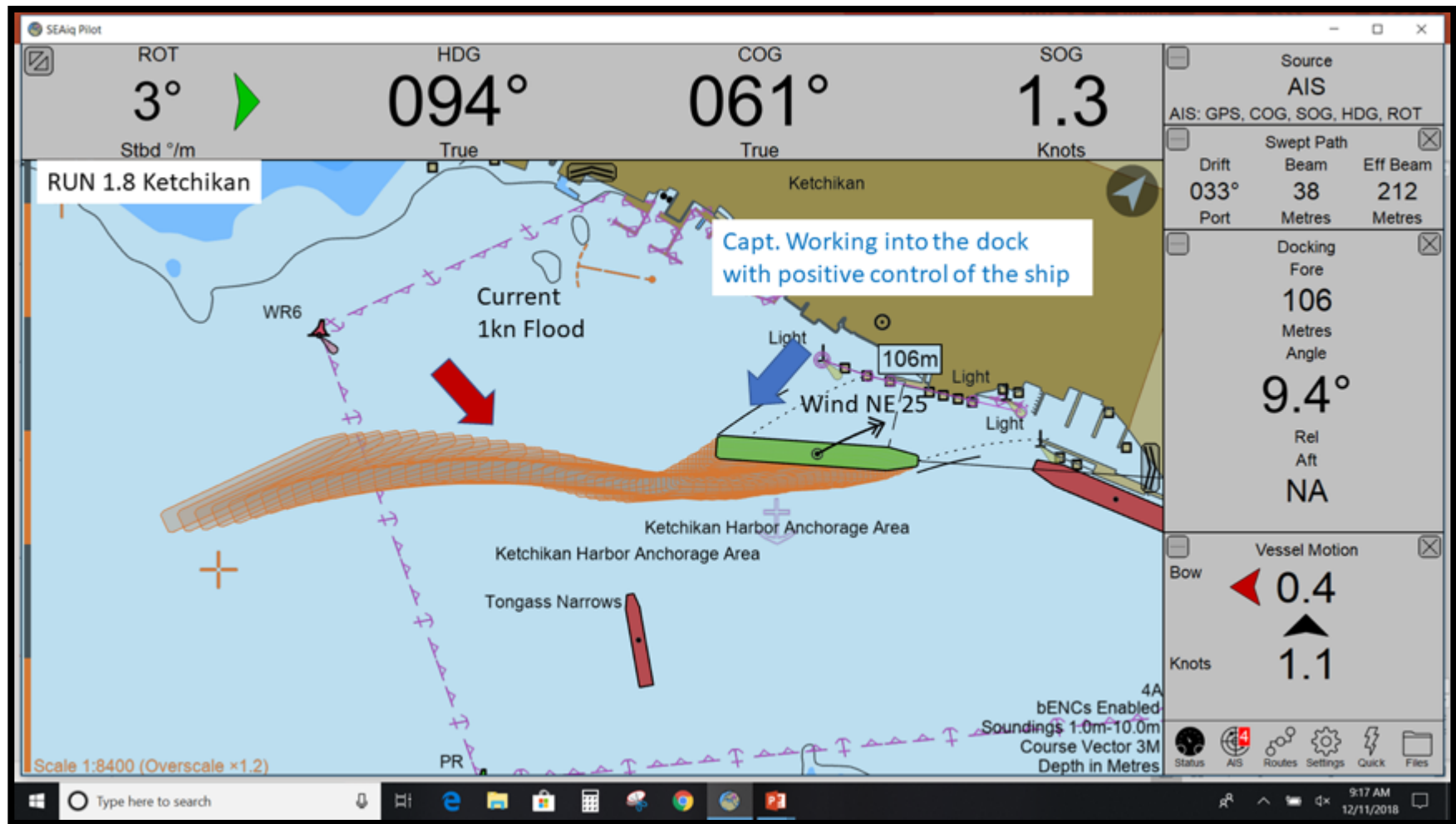
1st Run









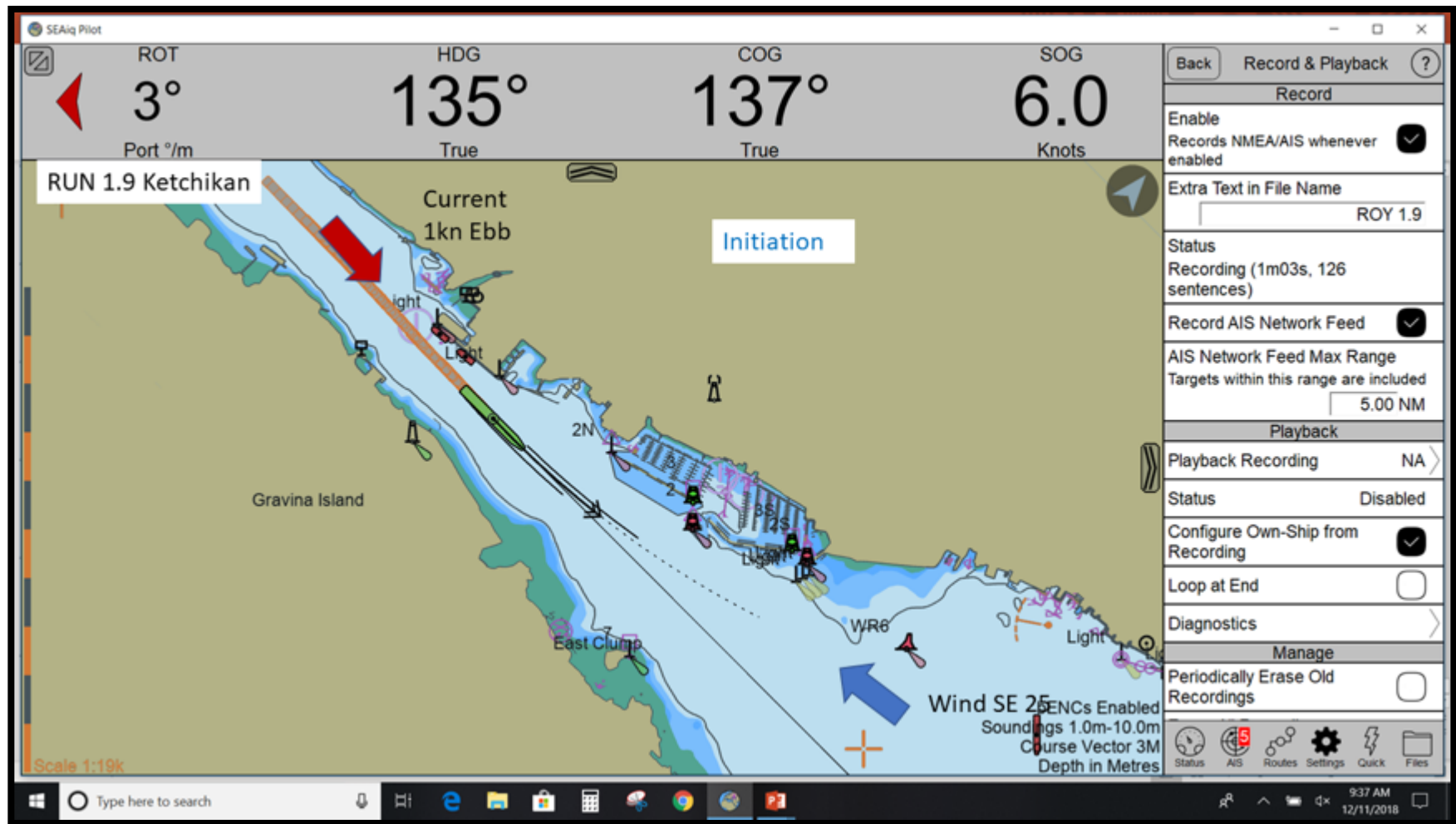


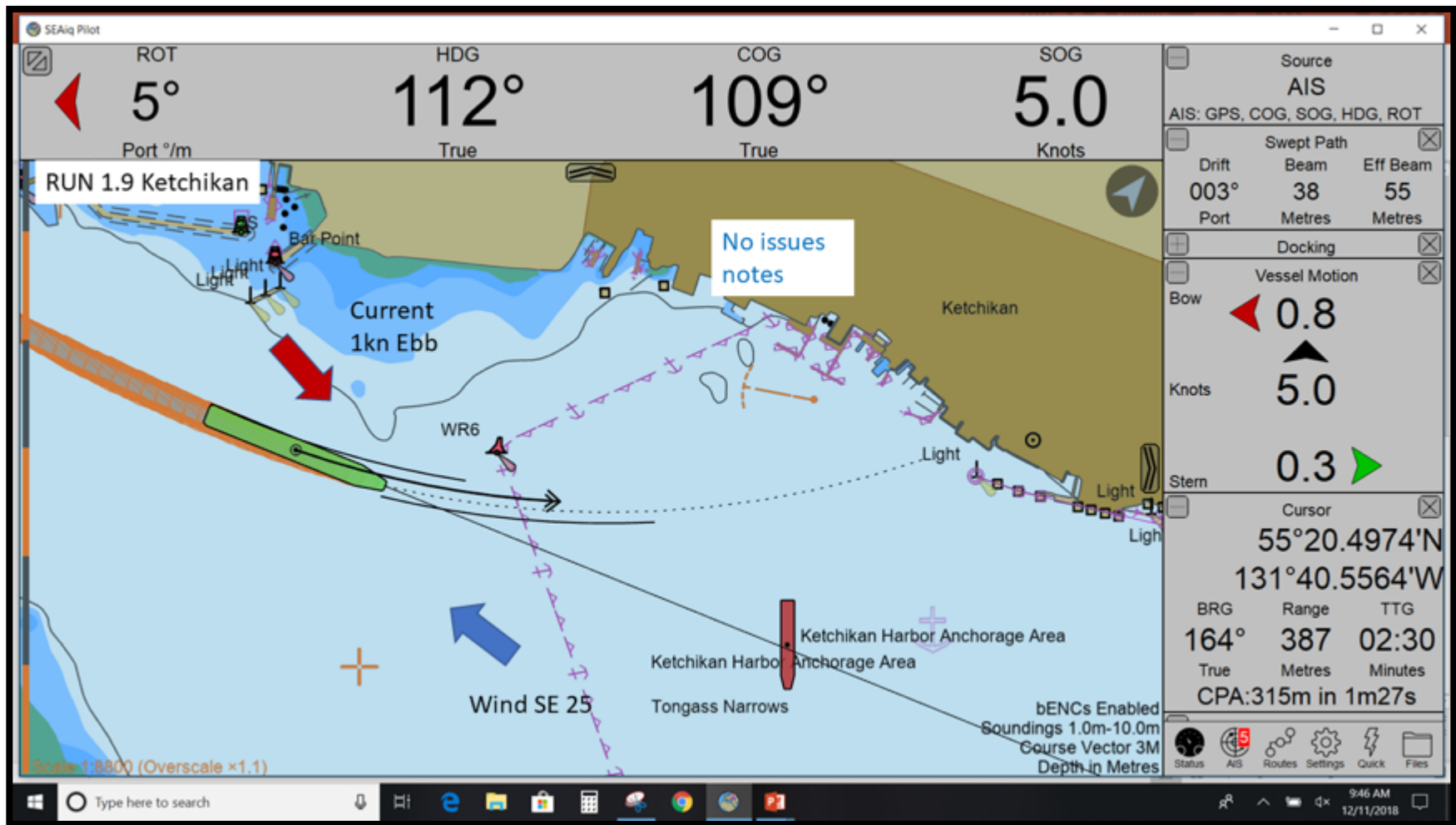
Run 1.9 Ketchikan, North Approach, SE25, 1kn Ebb

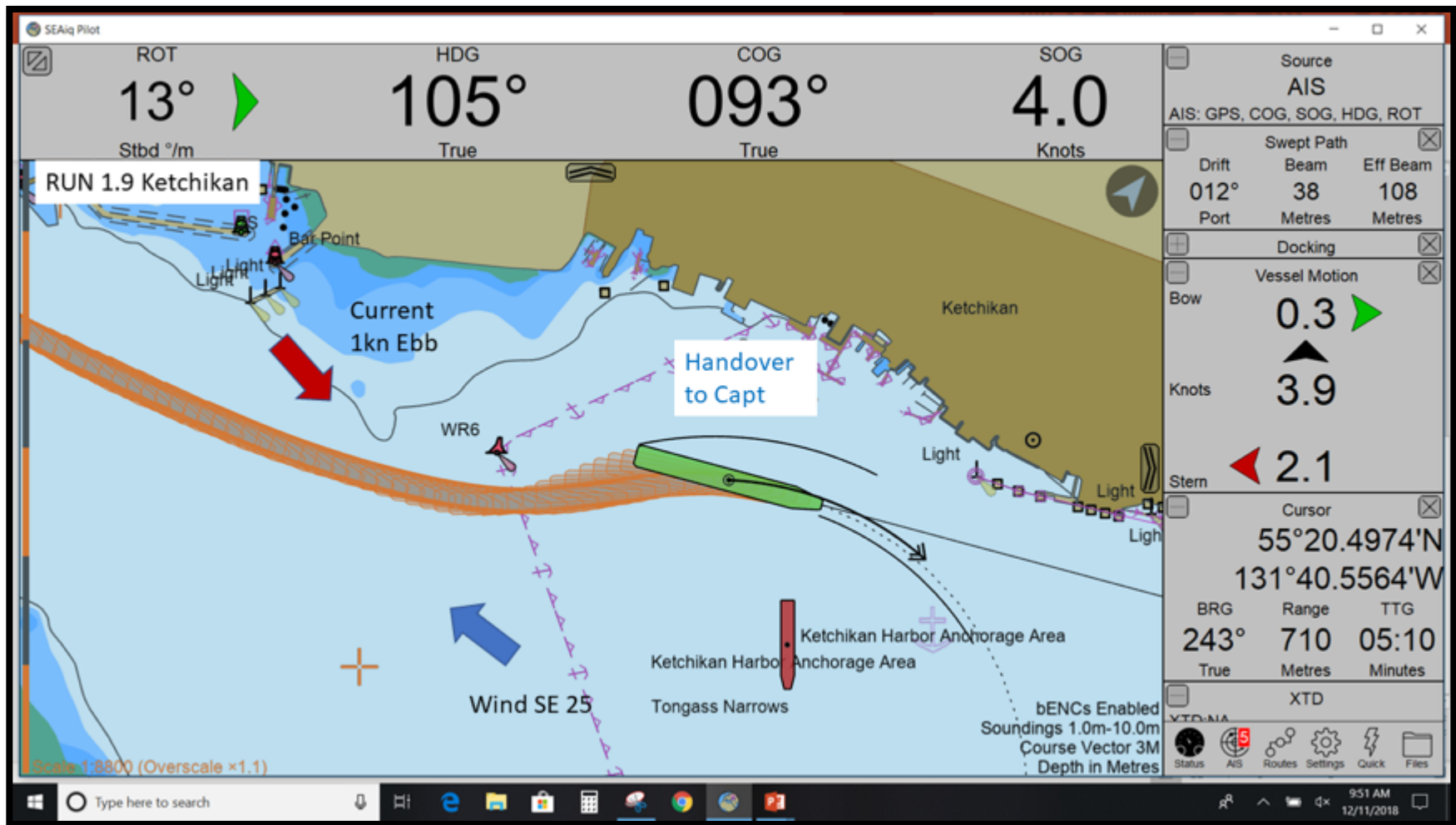
1.9 SE25 1kn Ebb, North Approach to Ketchikan

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2nd Run





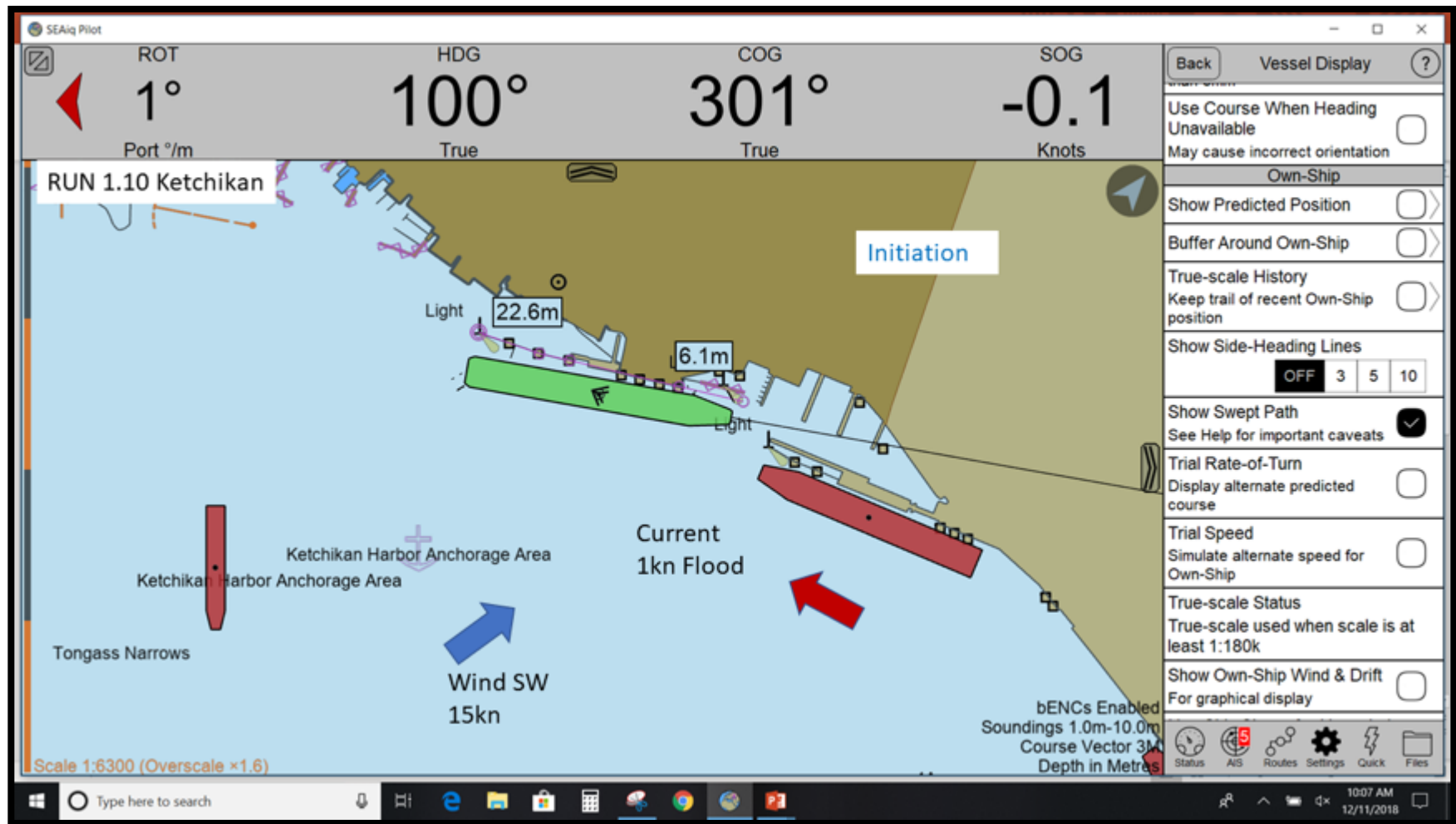


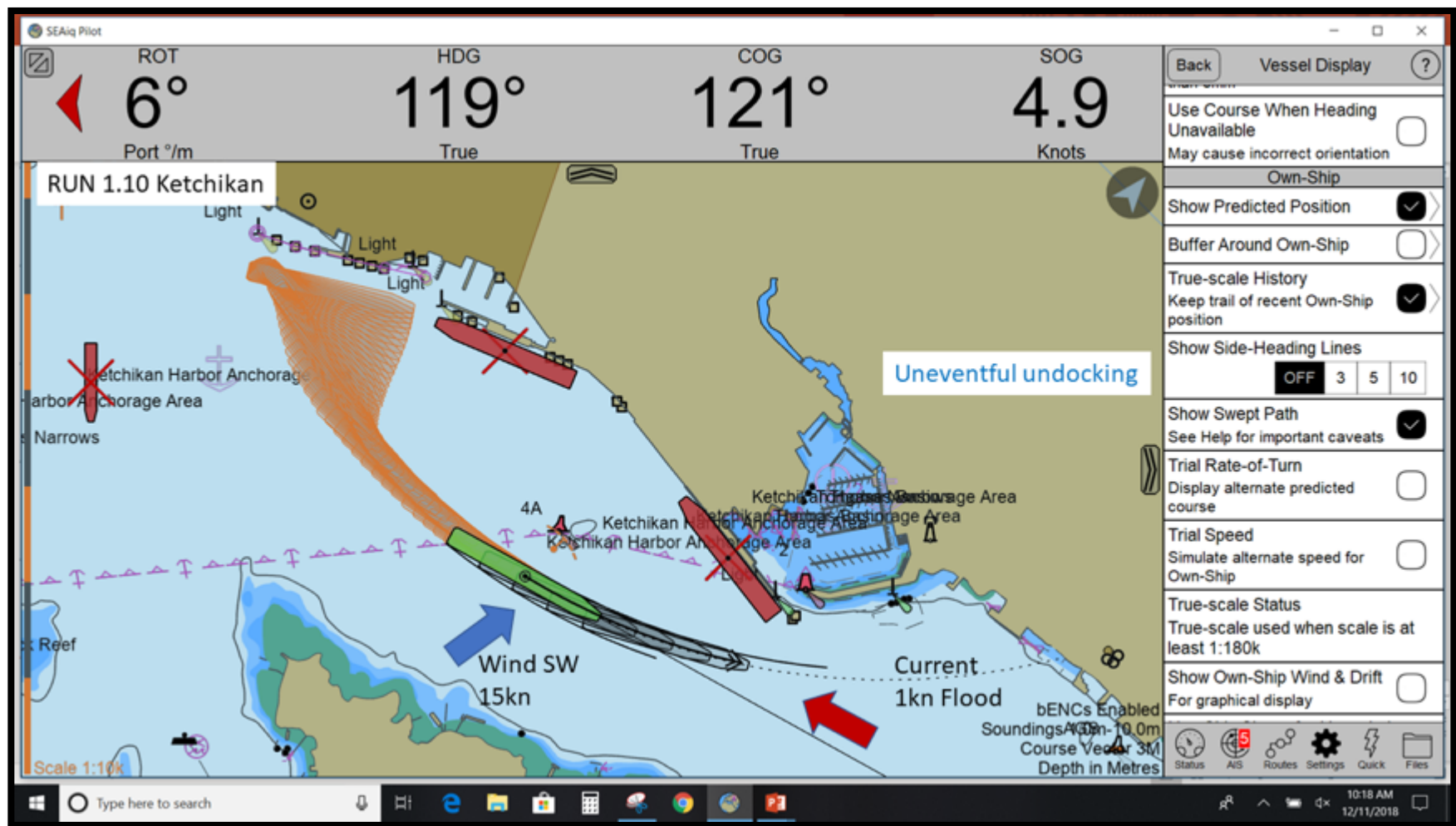
Run 1.10 Ketchikan, North Departure, SW15kn, 1kn Flood

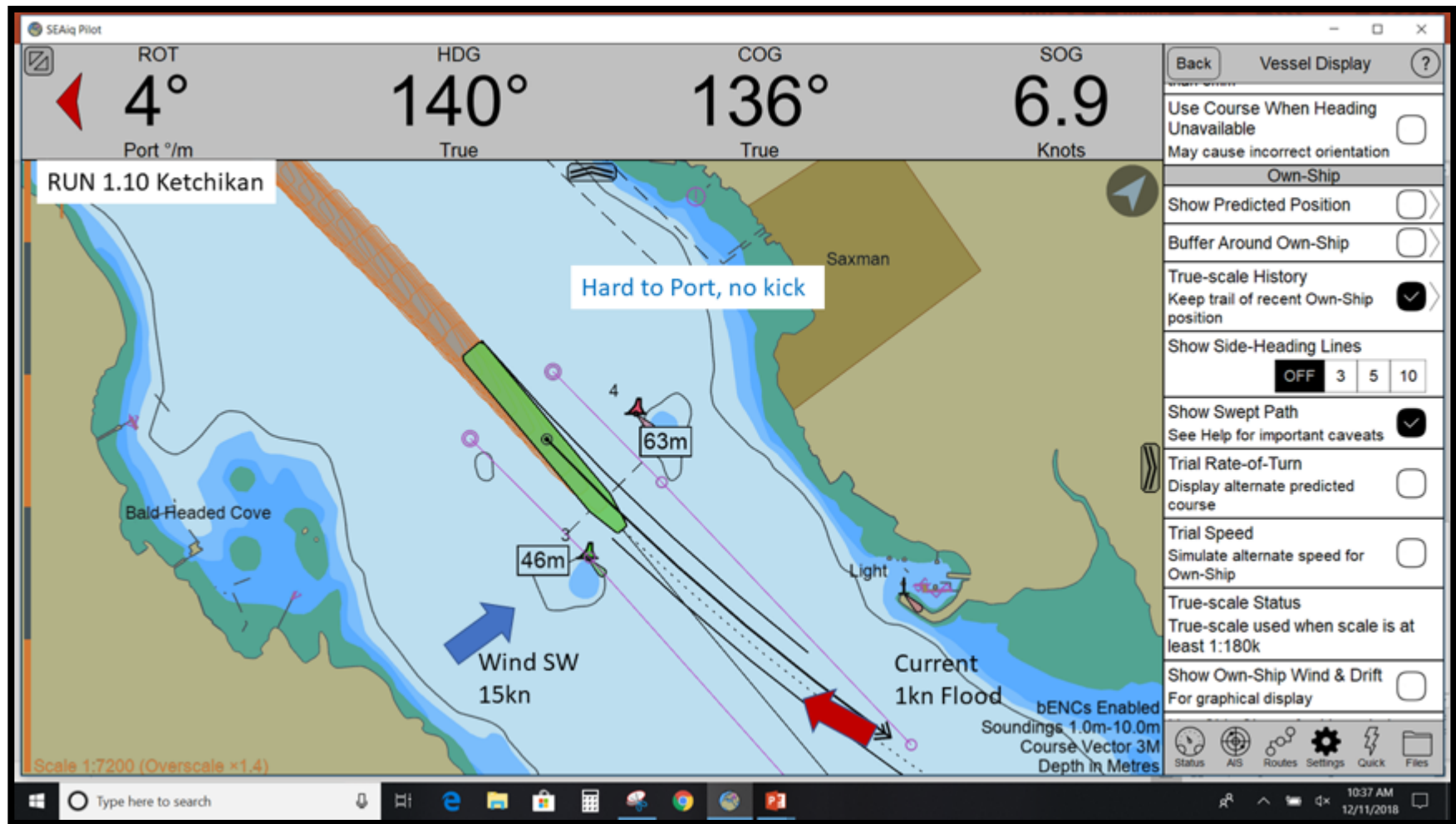
1.10 SW15 1kn Flood, North Departure Ketchikan

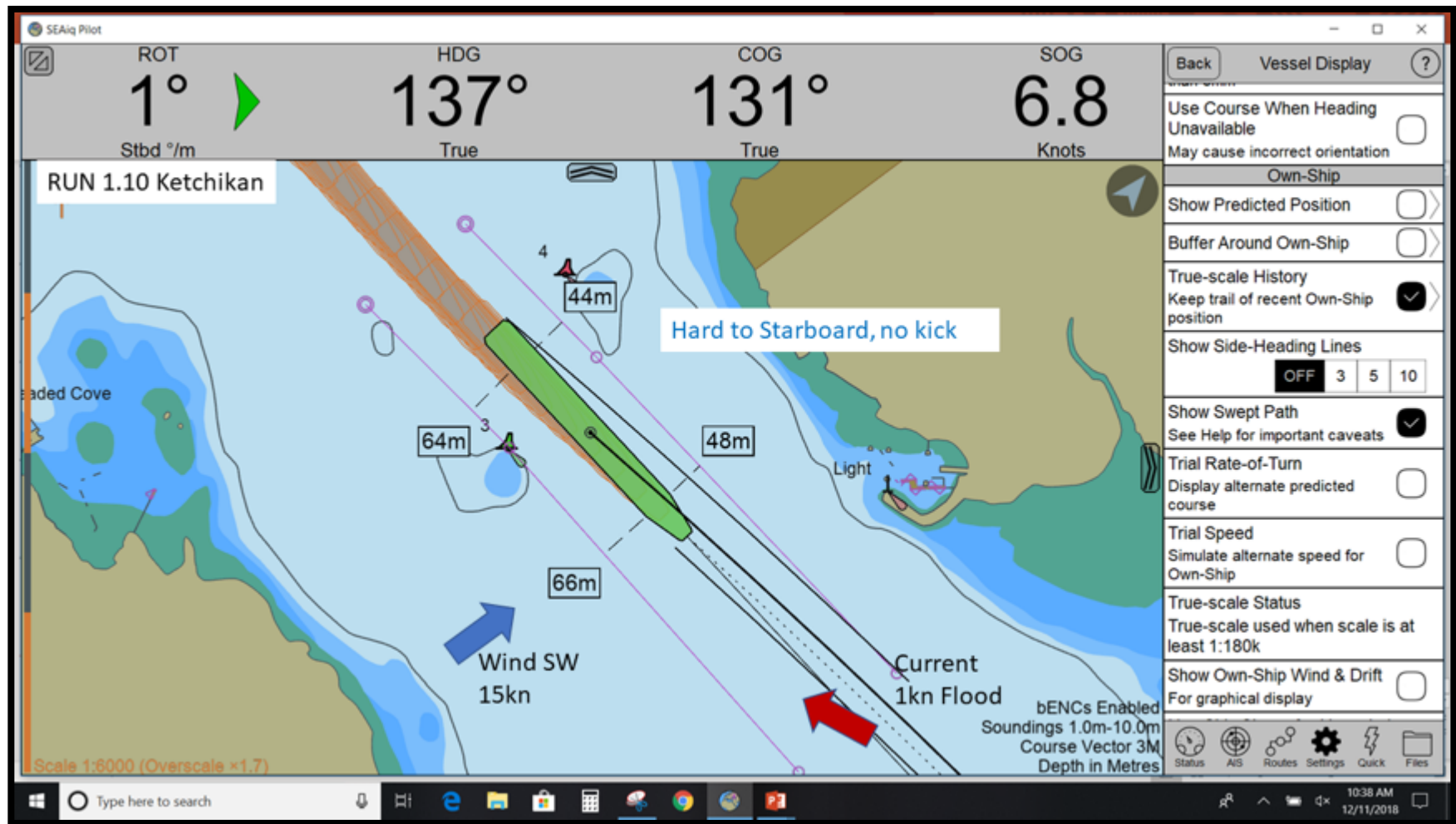
Tuesday 12/11/2018

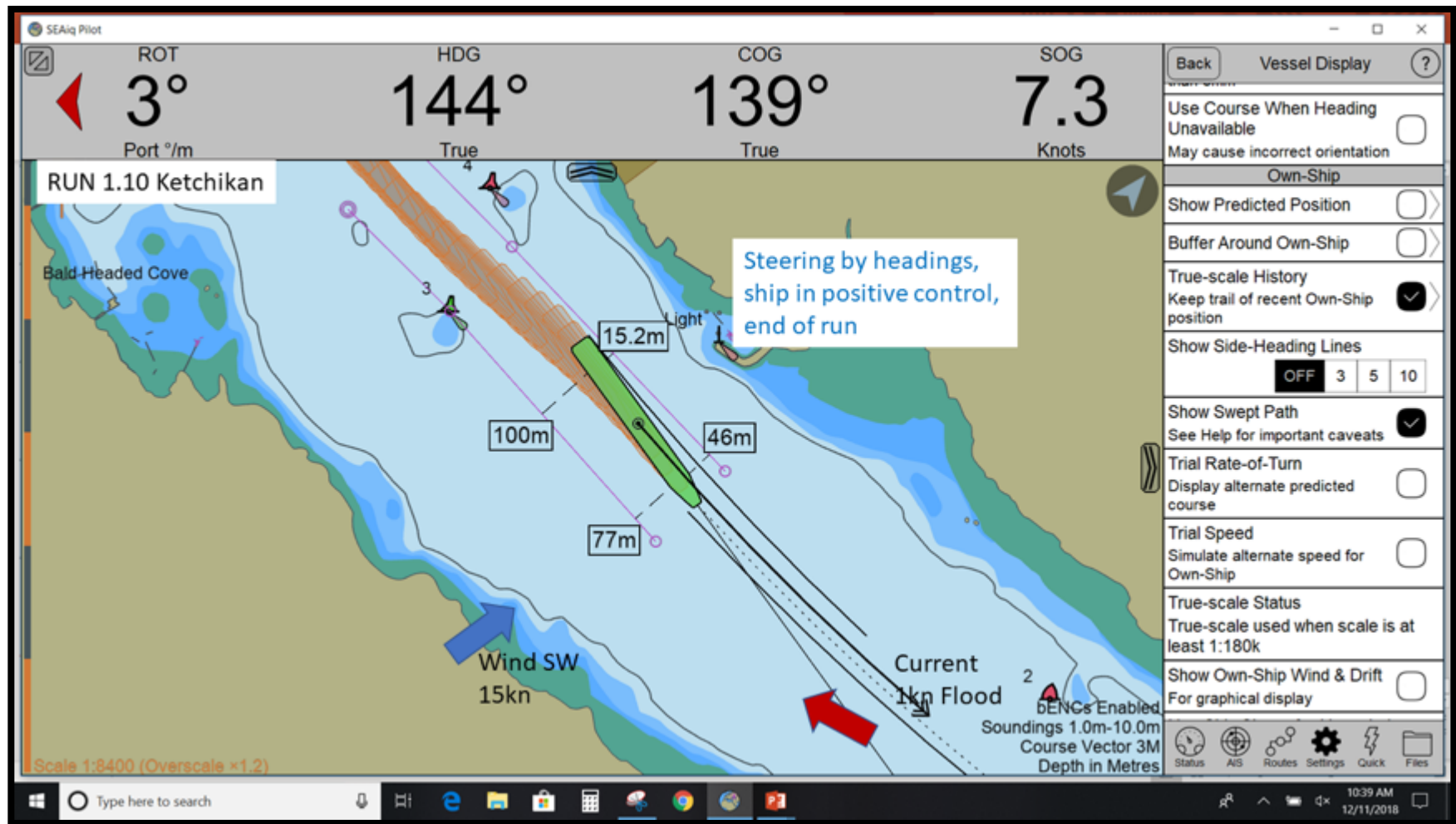
3rd Run









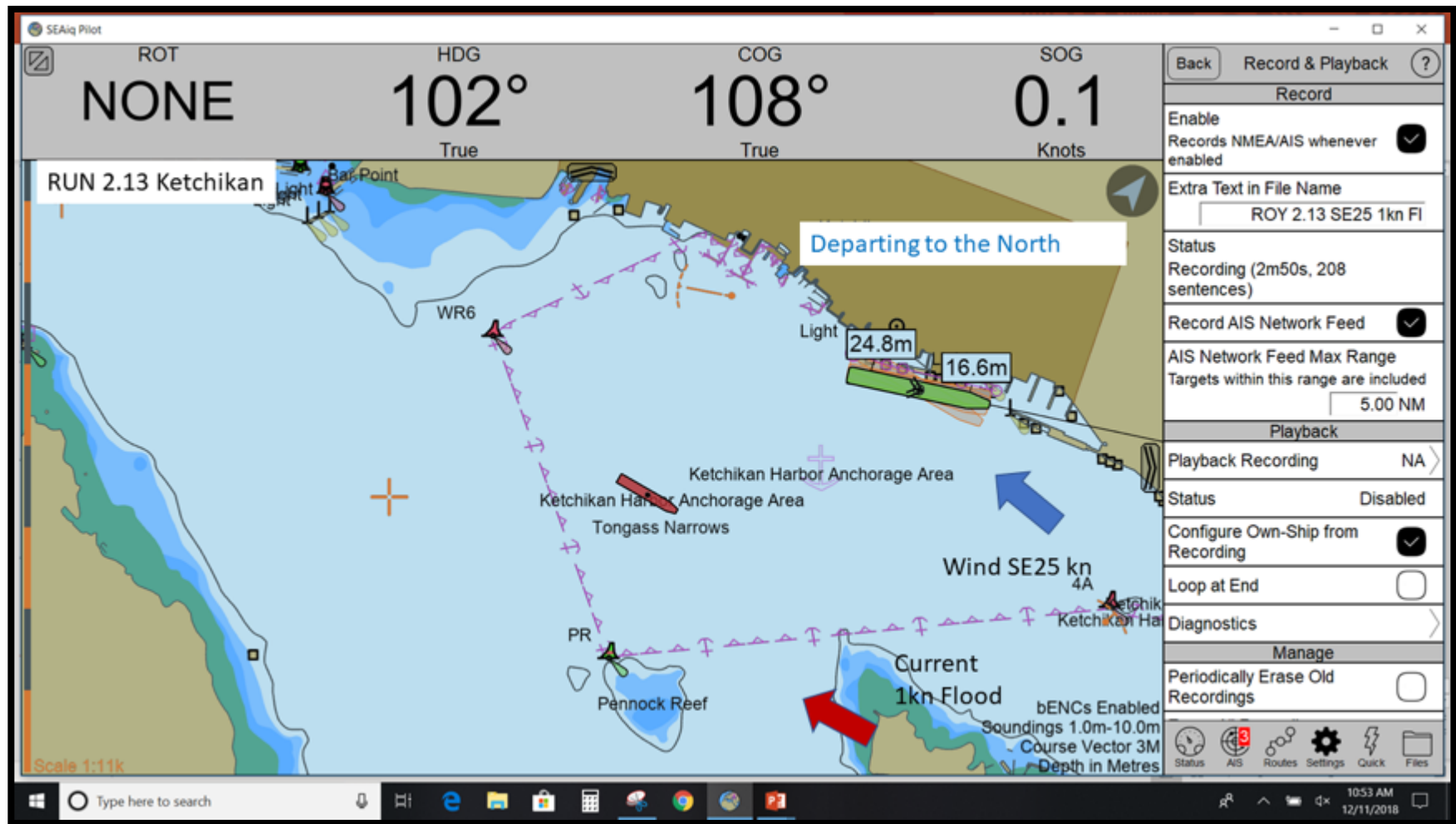


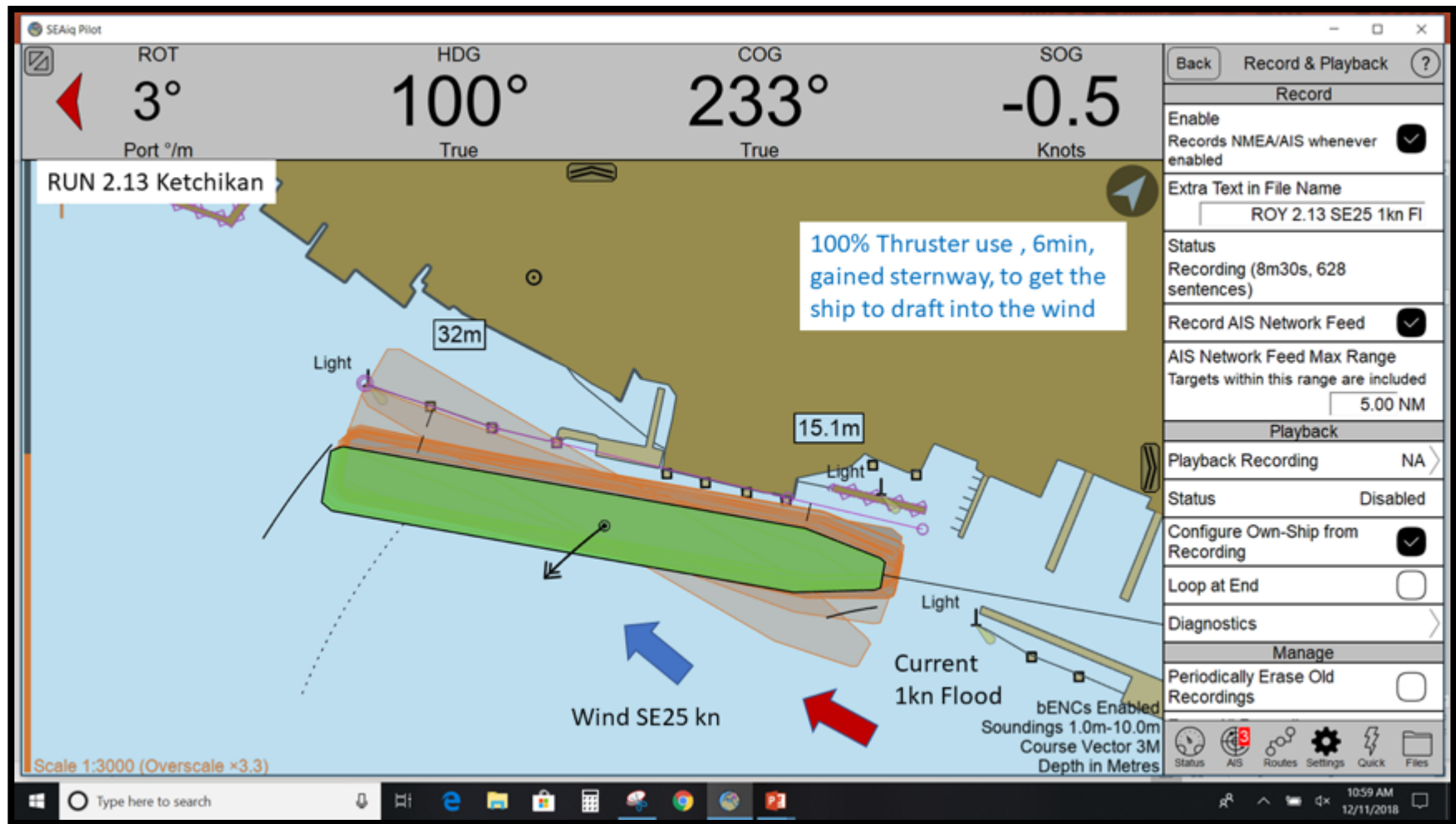
Run 2.13 Ketchikan, North Departure, SE@%, 1kn Flood

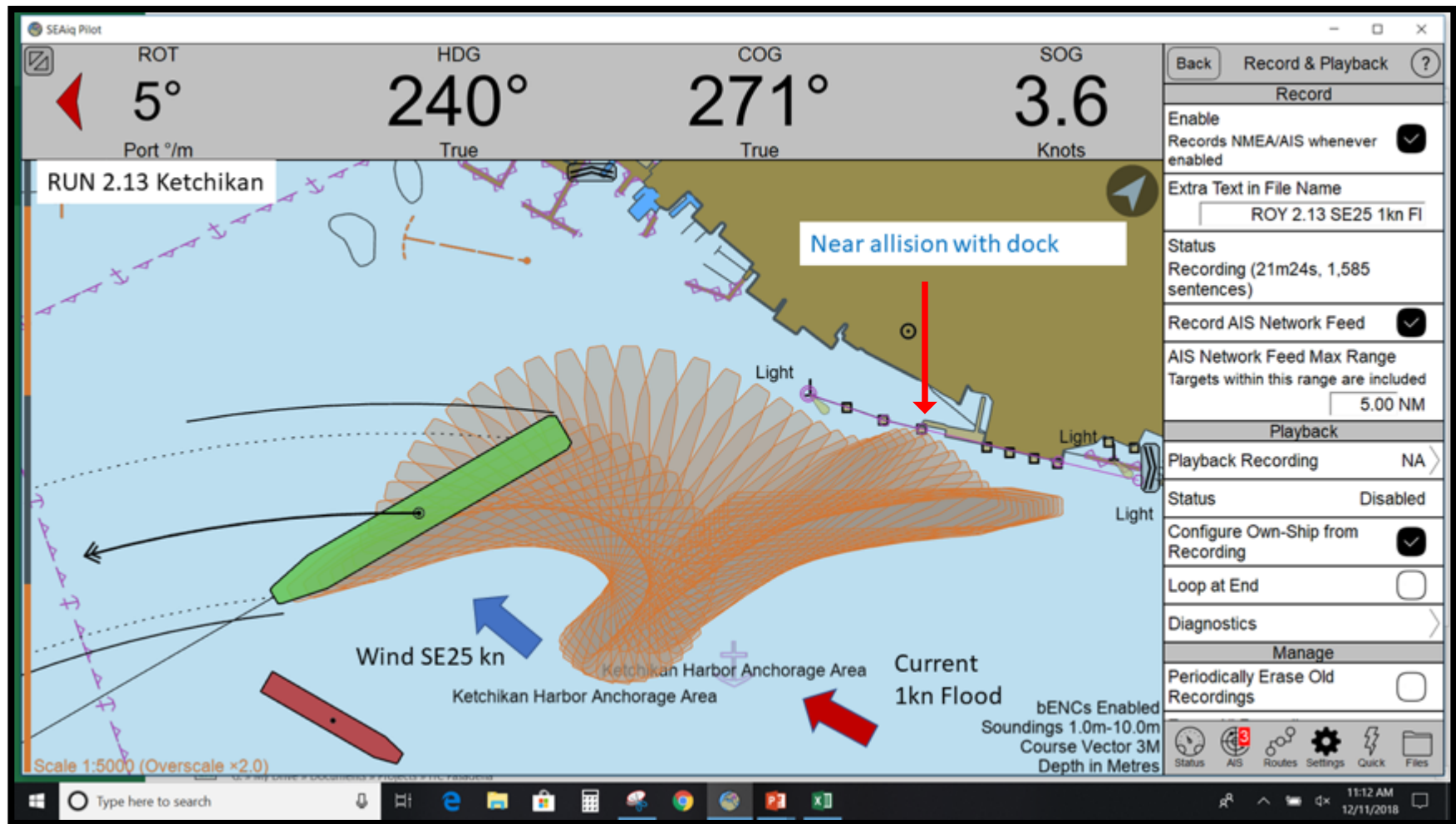
2.13 SE25 1kn Flood, North Departure Ketchikan

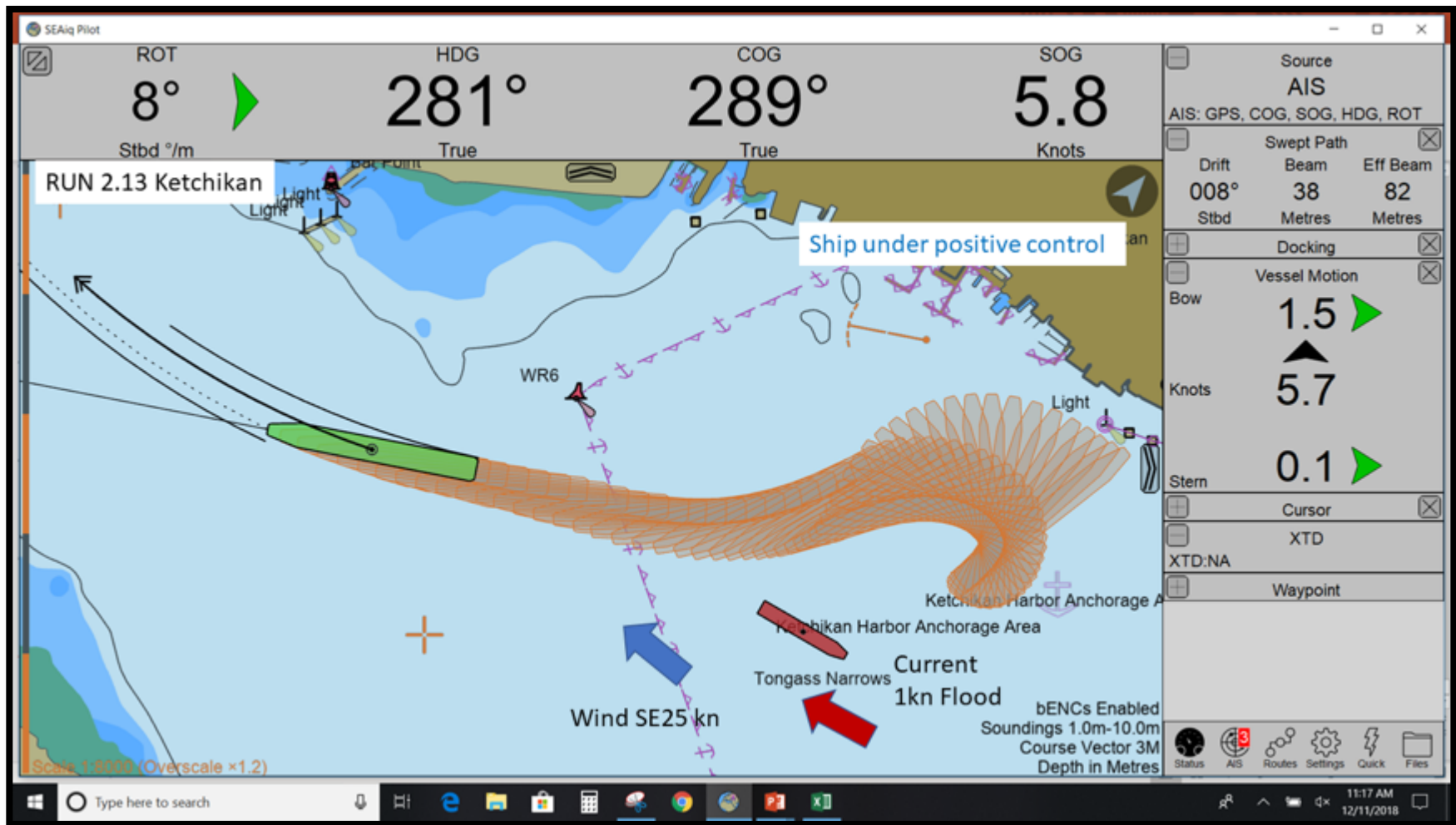
Tuesday 12/11/2018

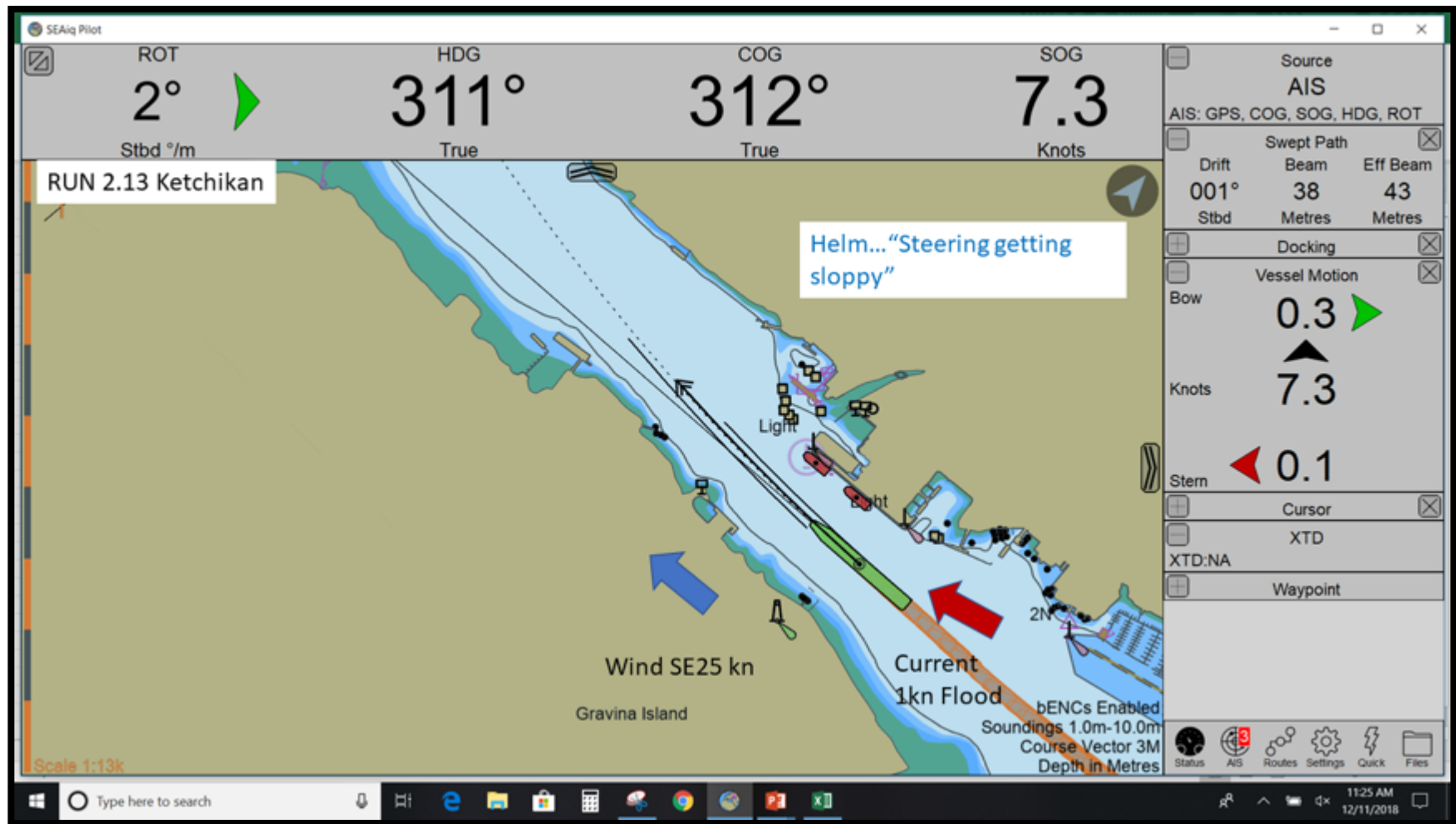
4th Run

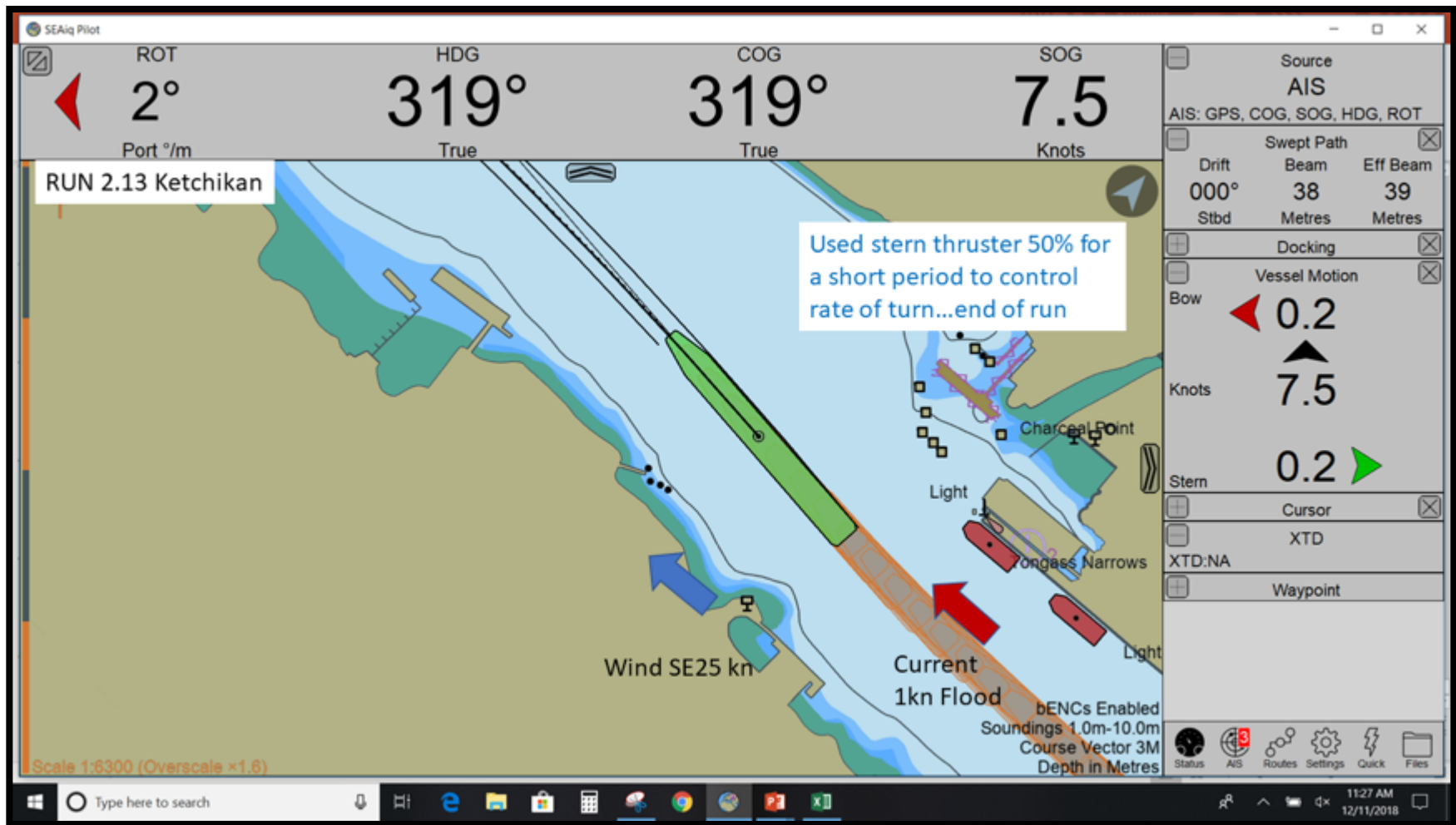










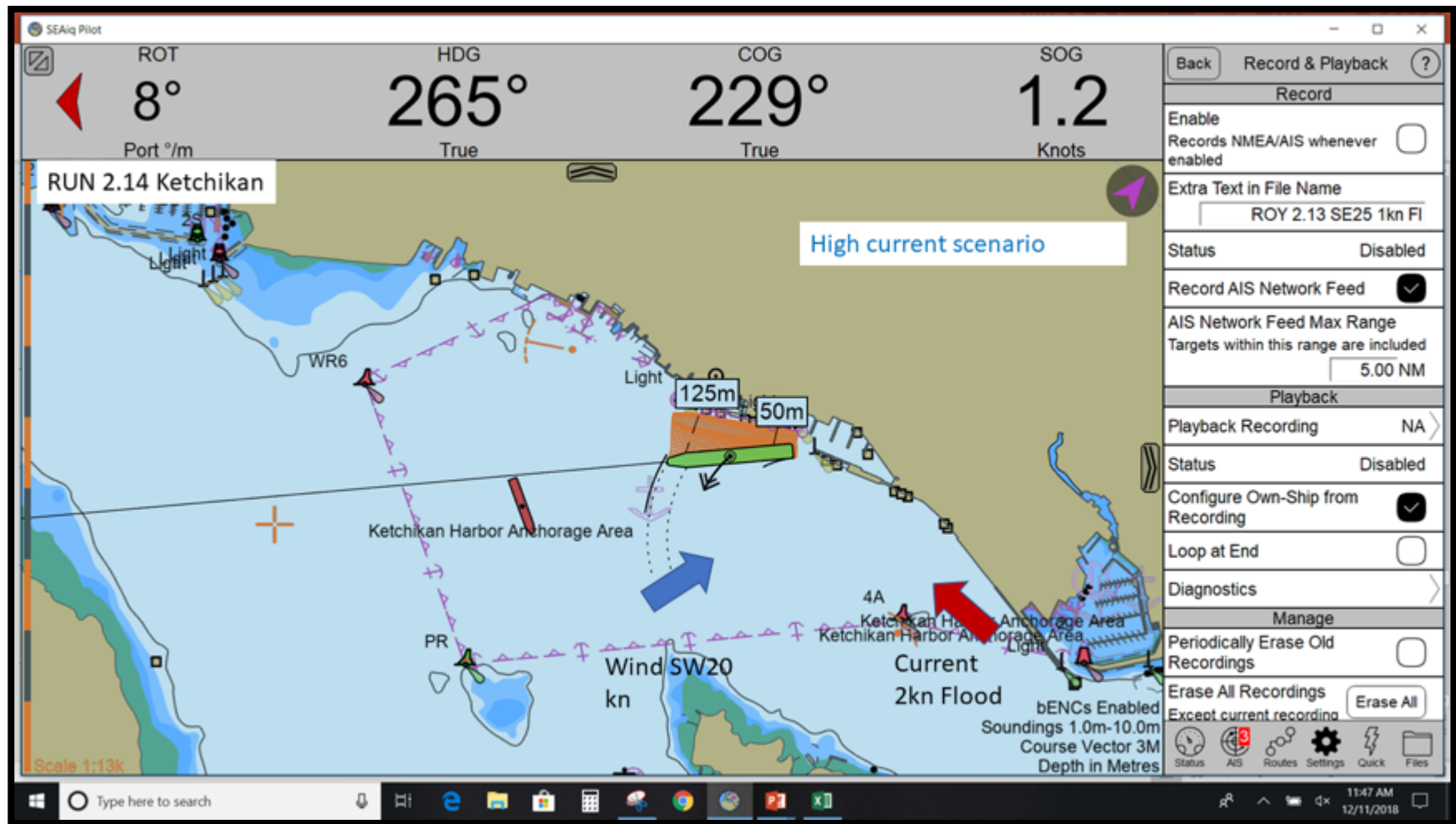


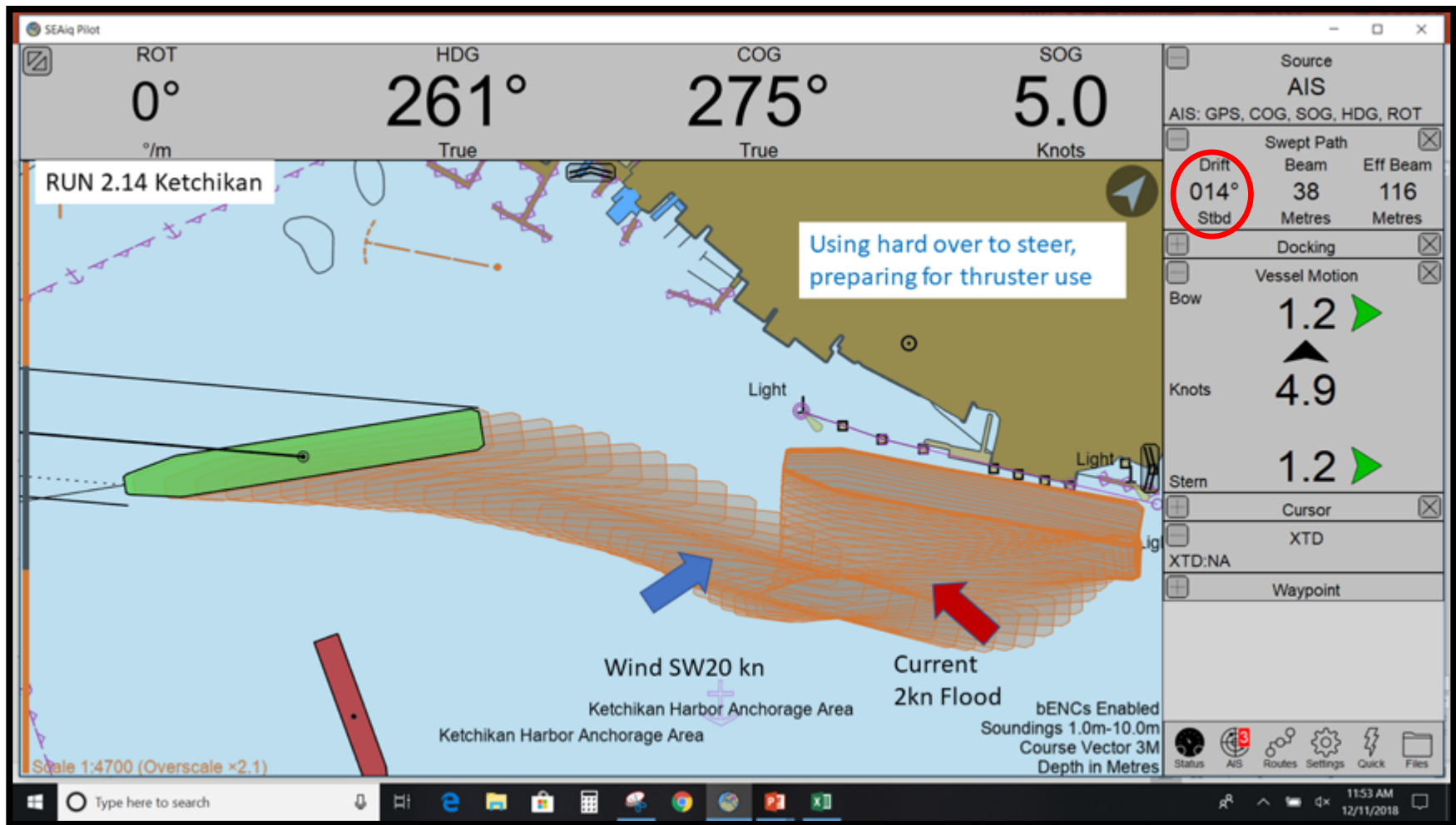
Run 2.14 Ketchikan, North Departure, SW20kn, 2.0kn Flood

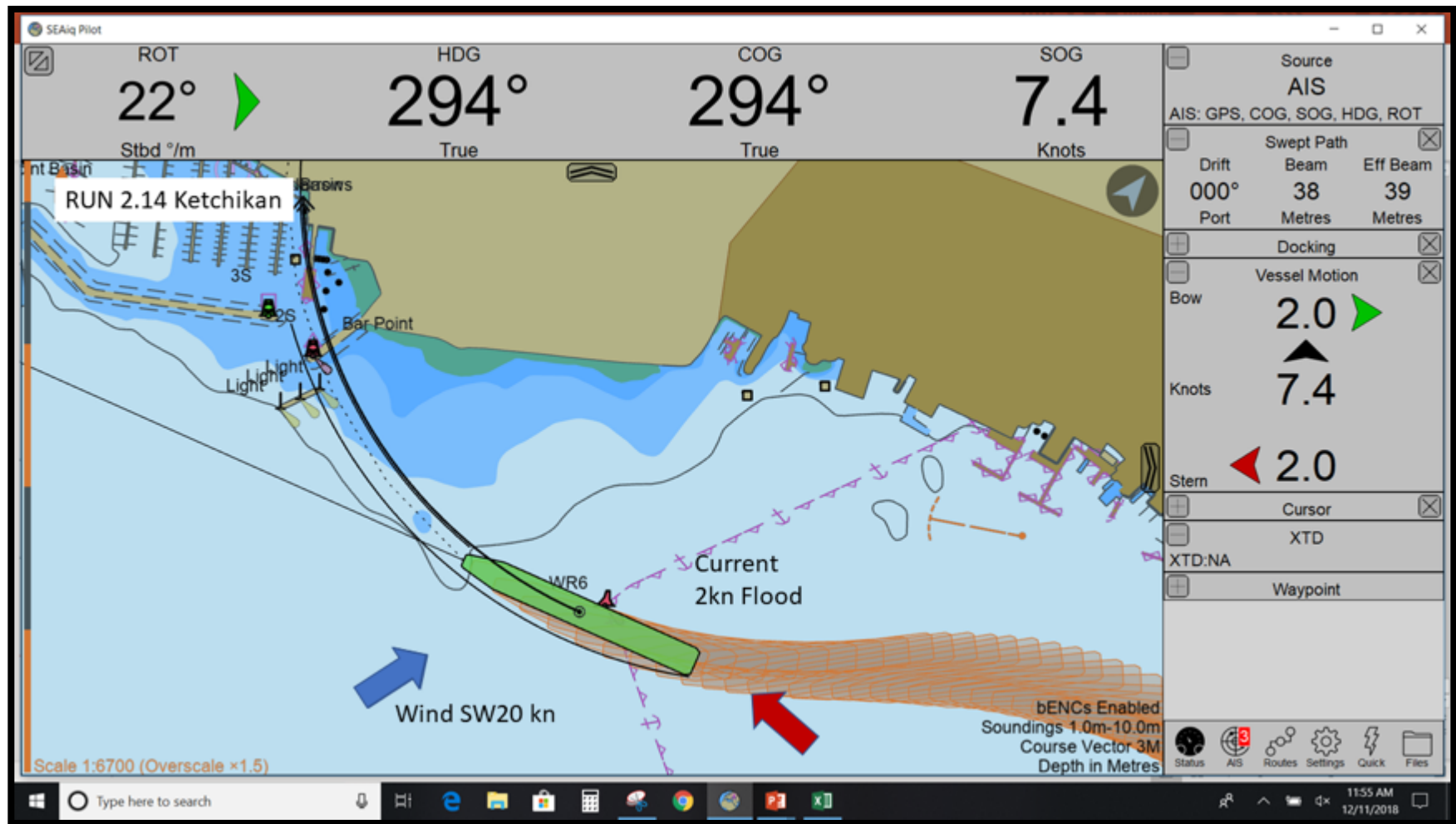
2.14 SW20 2.0 Flood, North Depart Ketchikan

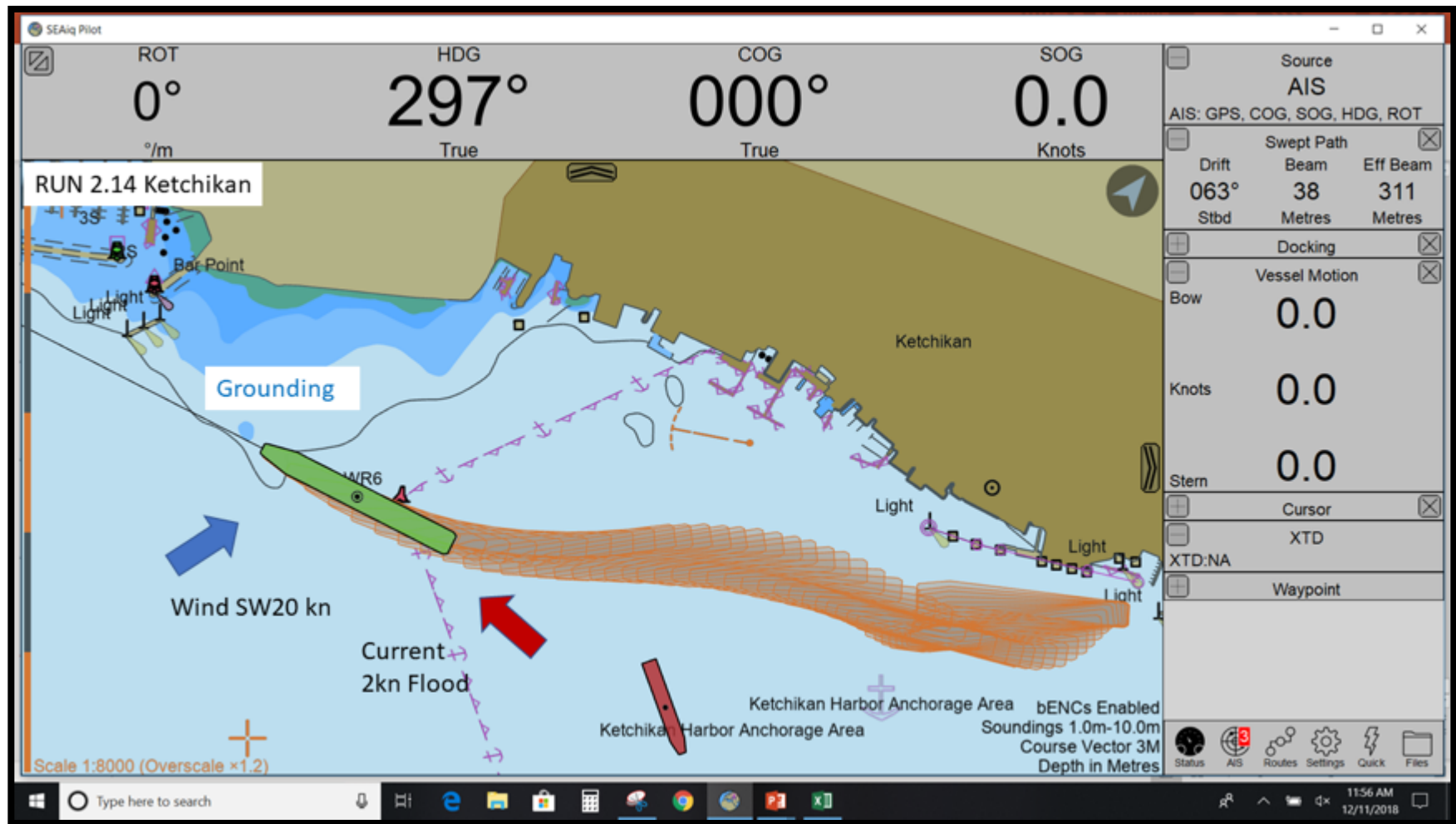
Tuesday 12/11/2018

5th Run







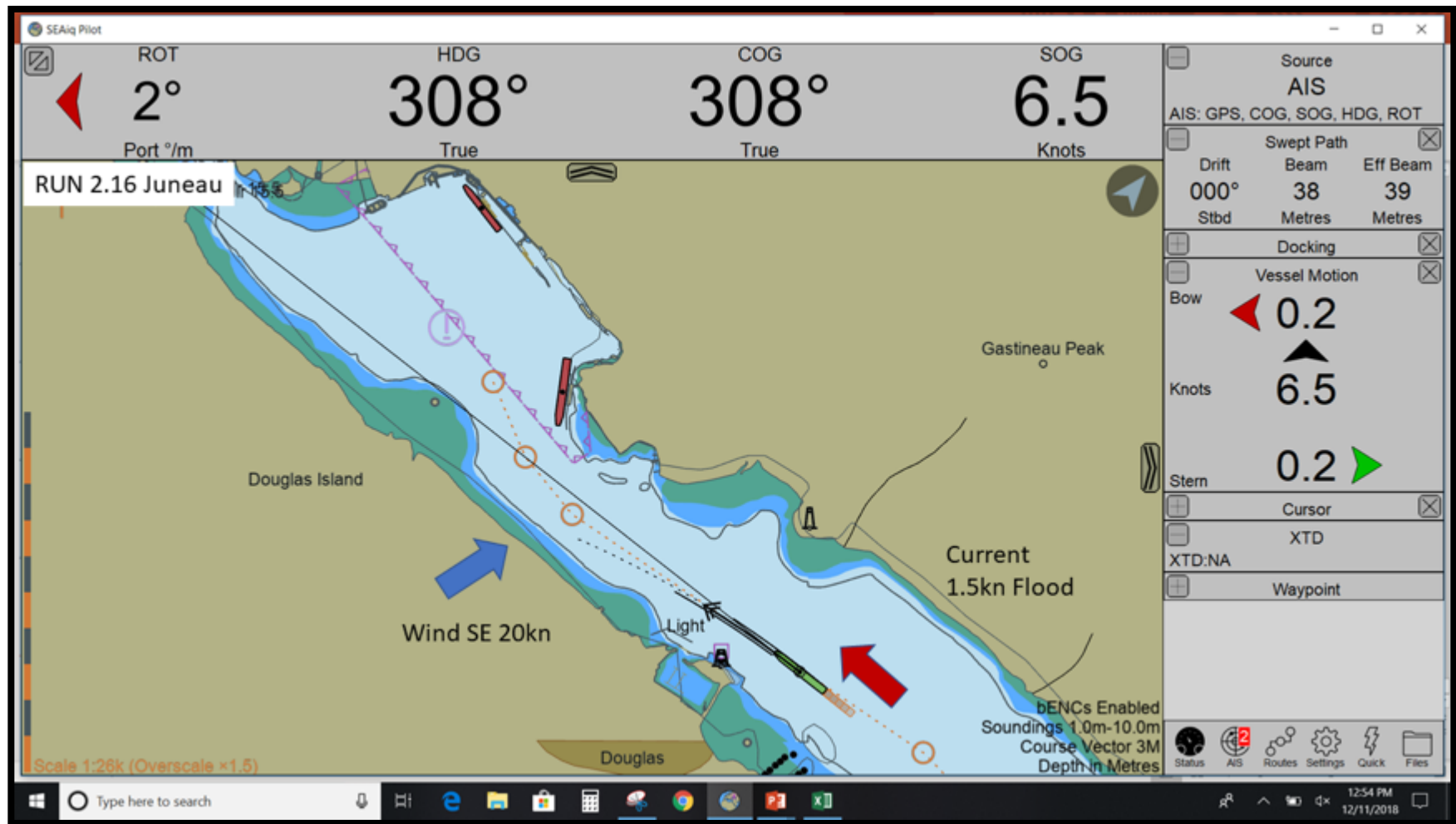


Run 2.16 Juneau, Arrival, SE20kn, 1.5Flood

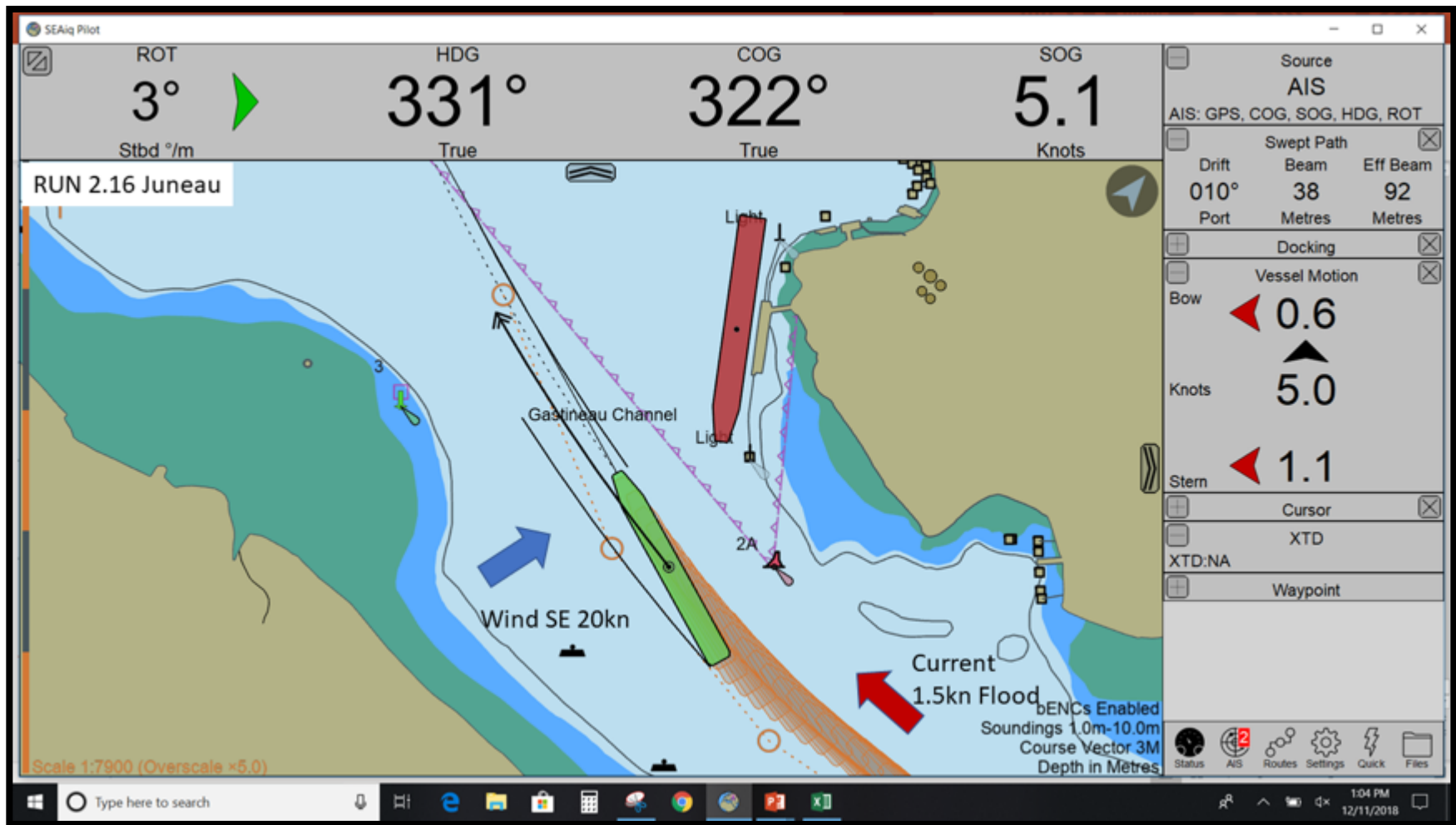
2.16 SE20 1.5Flood, Arrival Juneau

Tuesday 12/11/2018

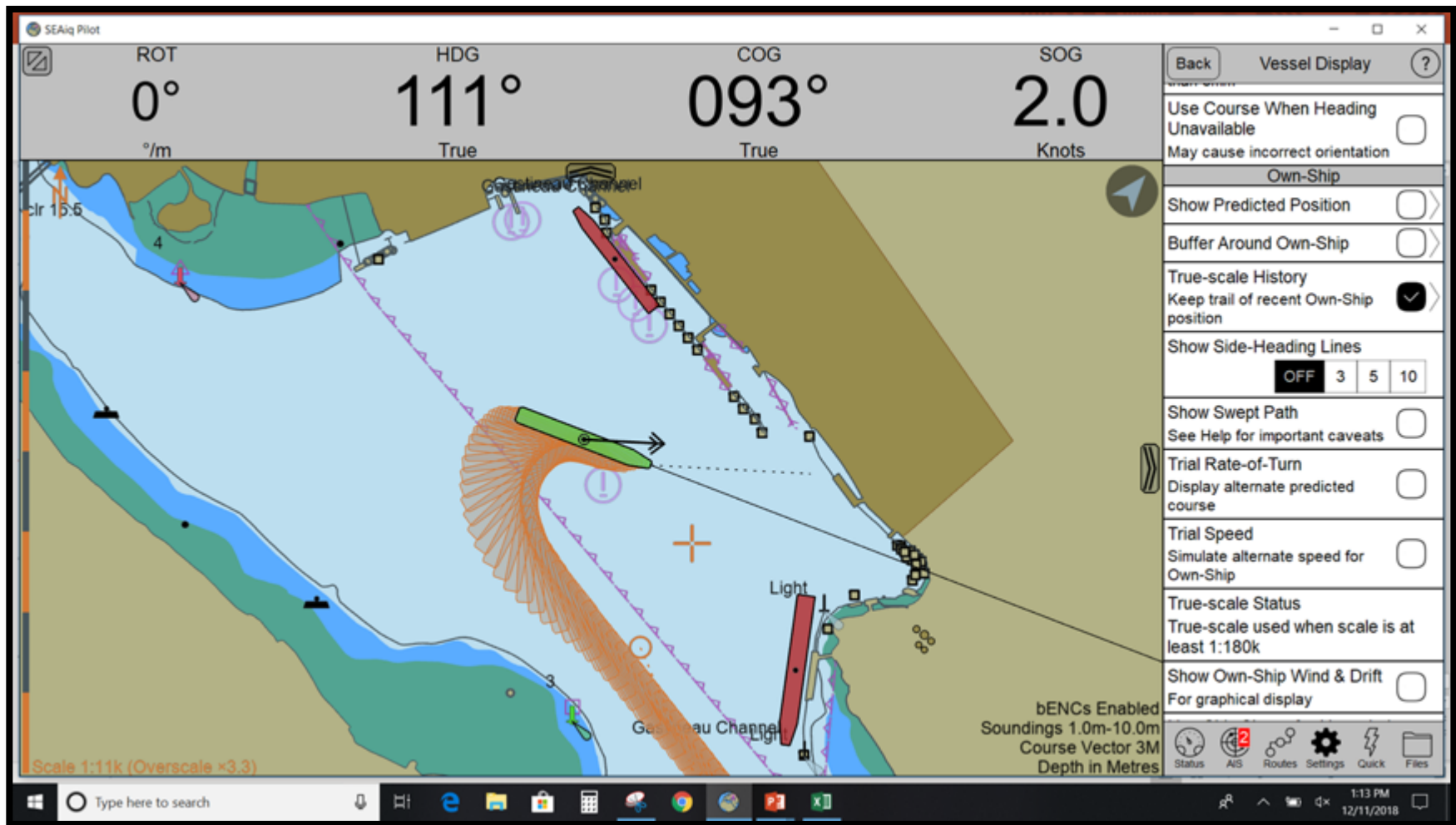
6th Run









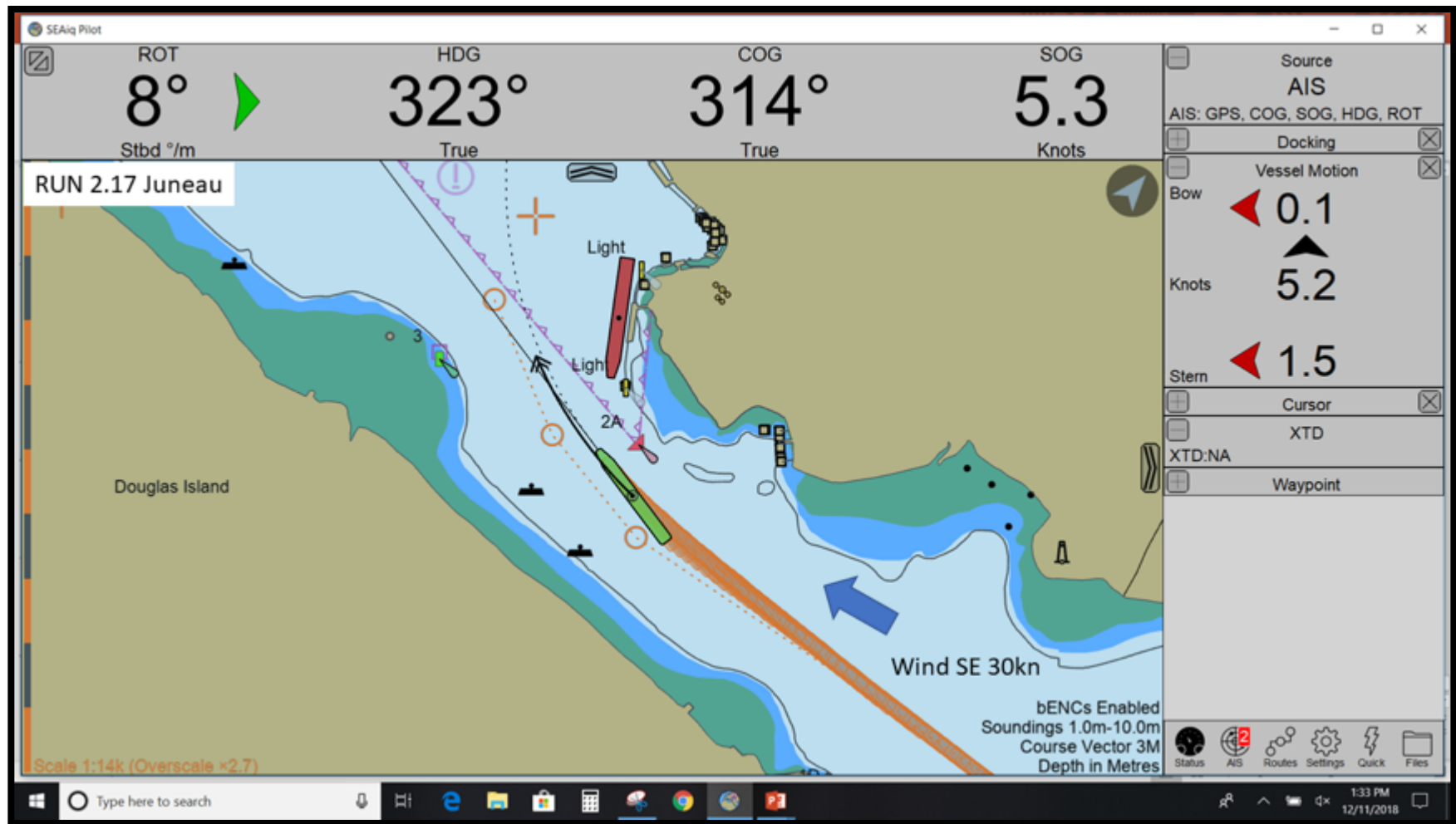


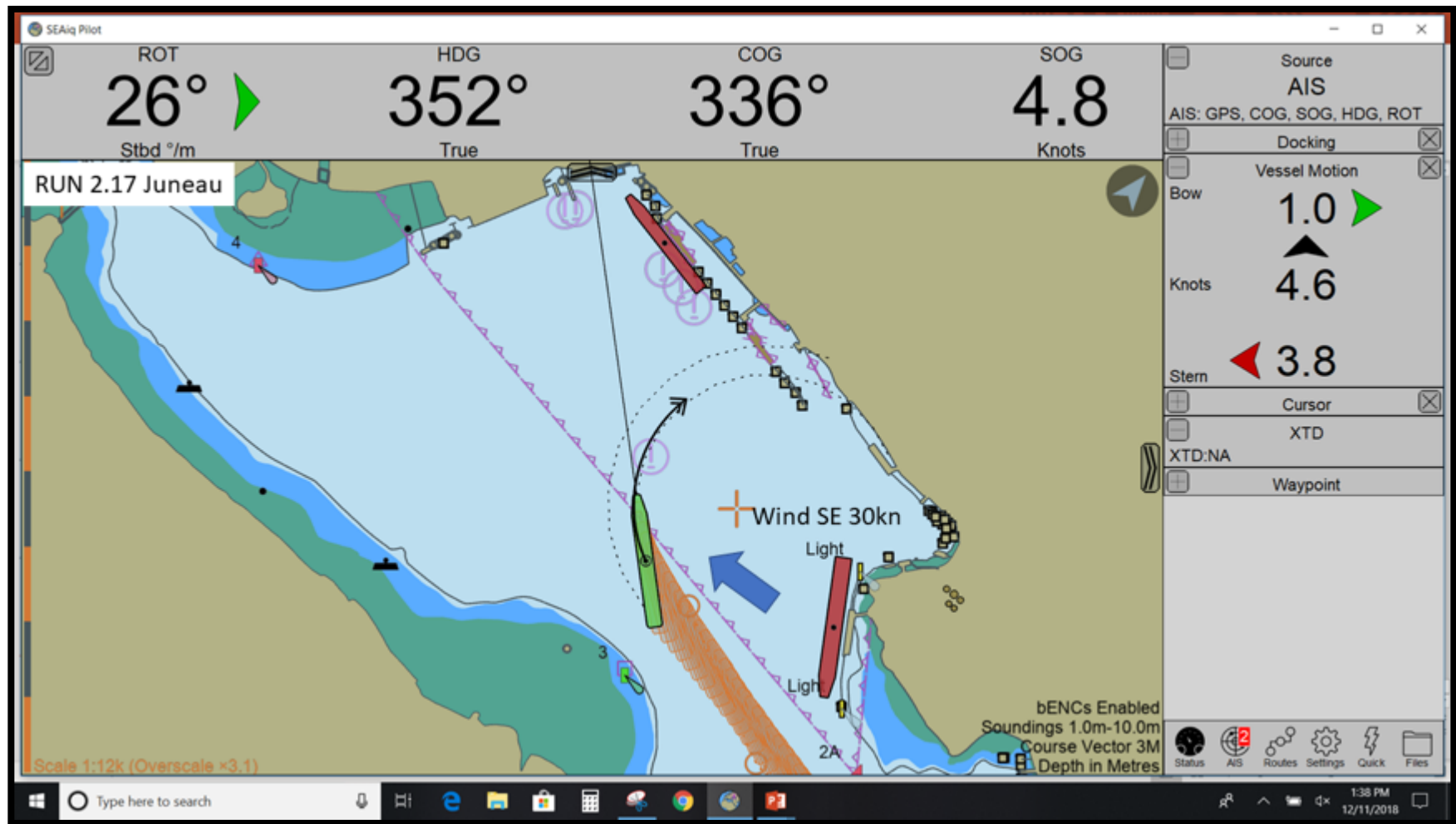
Run 2.17 Juneau, Arrival, SE30kn, 0 Flood

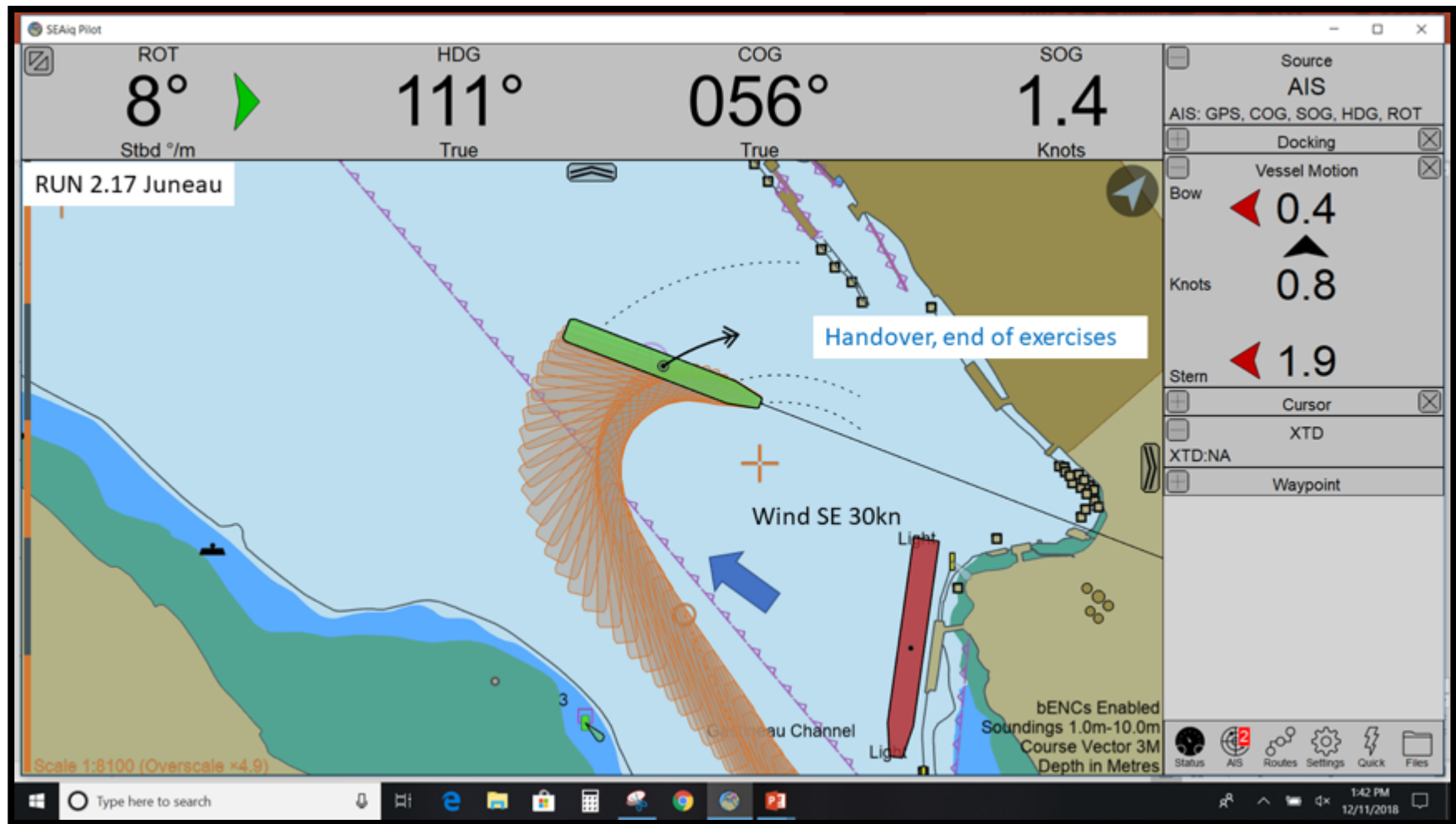
2.17 SE30, 0 Current, Arrival Juneau

Tuesday 12/11/2018

7th Run





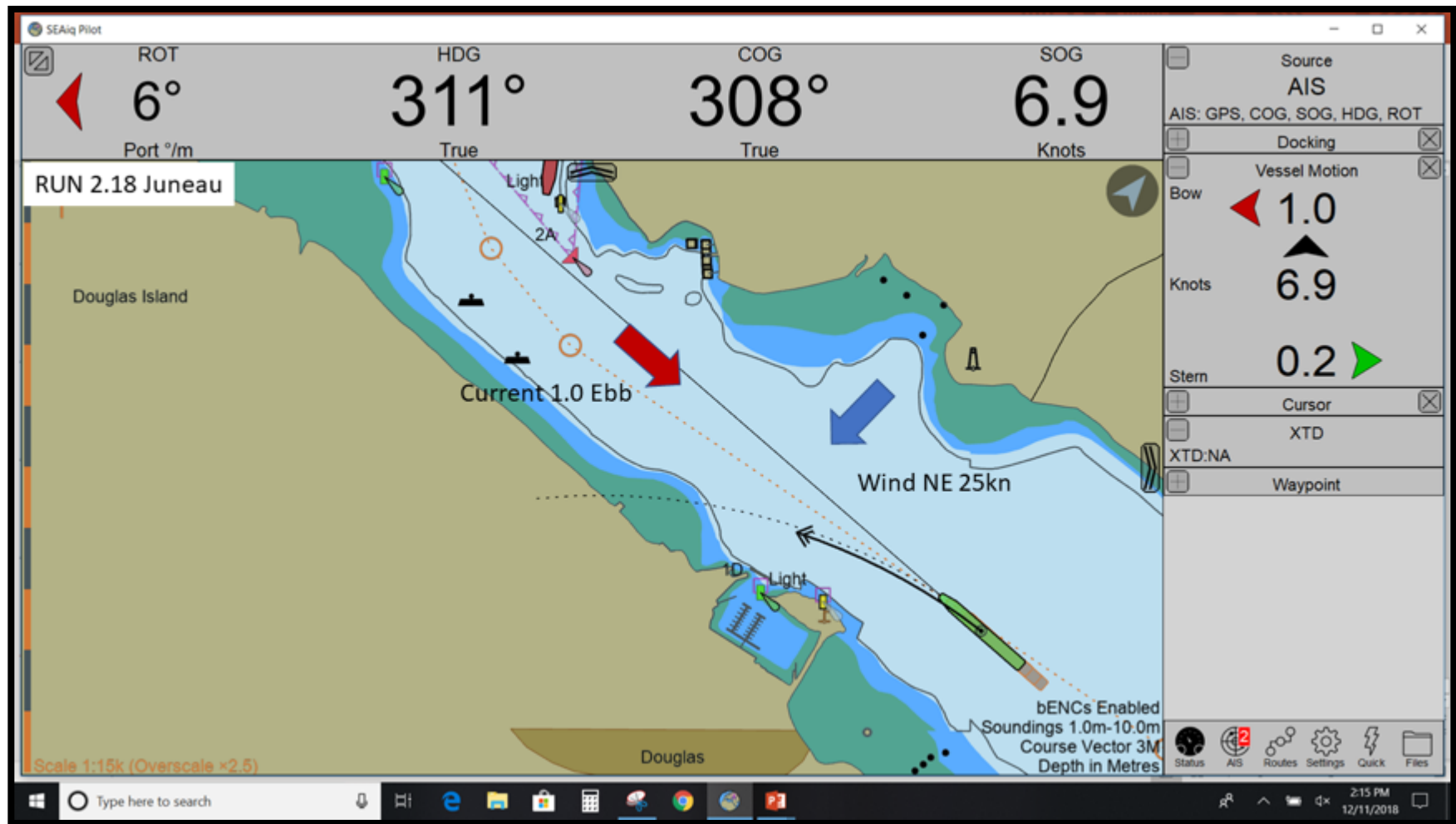


Run 2.18 Juneau, Arrival, NE25kn, 1kn Ebb

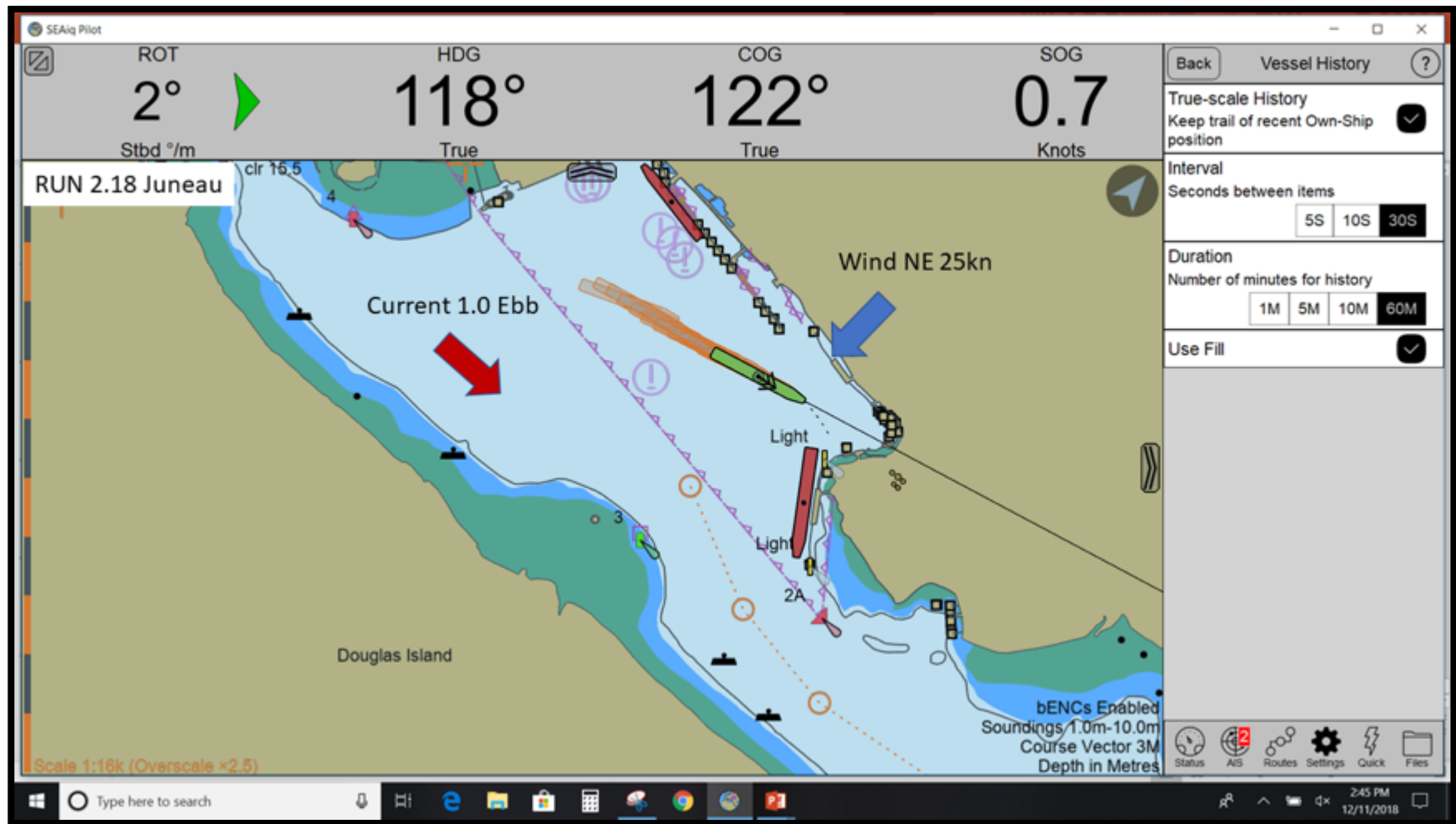
2.18 NE 25kn, 1kn Ebb, Arrival Juneau

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8th Run





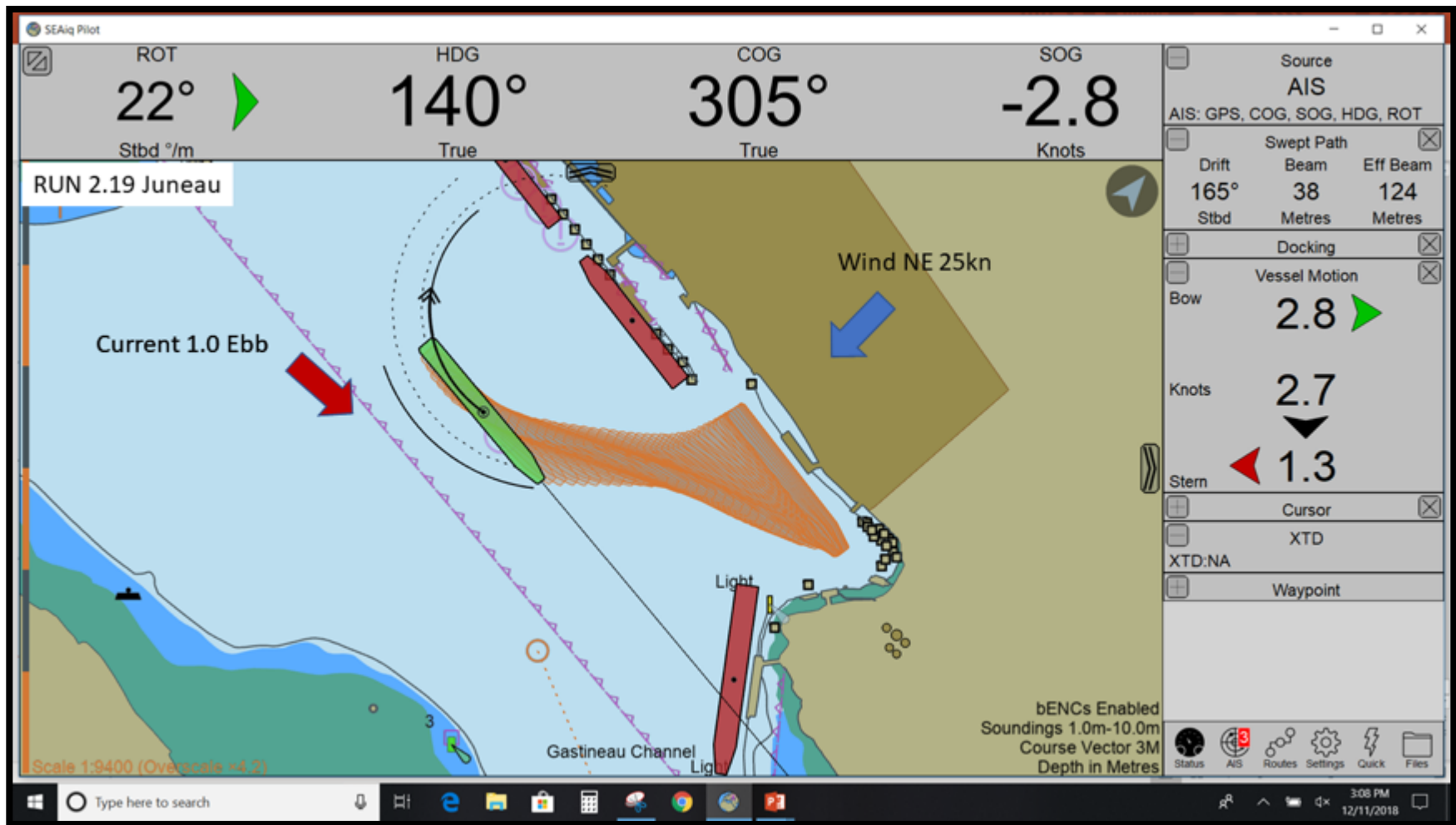


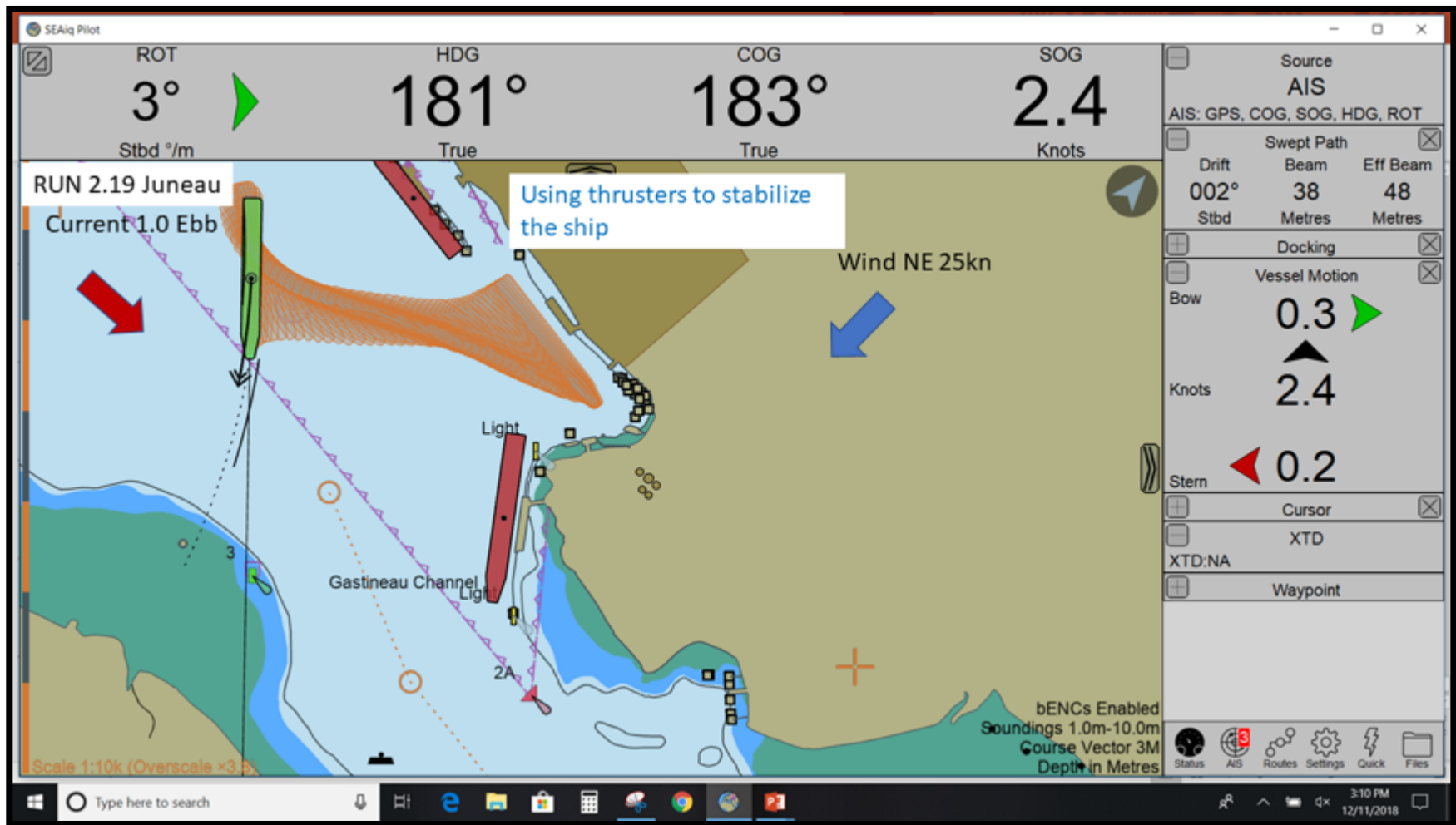
Run 2.19 Juneau, Arrival, NE 25Kn, 1kn Ebb

2.19 NE 25kn, 1kn Ebb, Juneau Departure

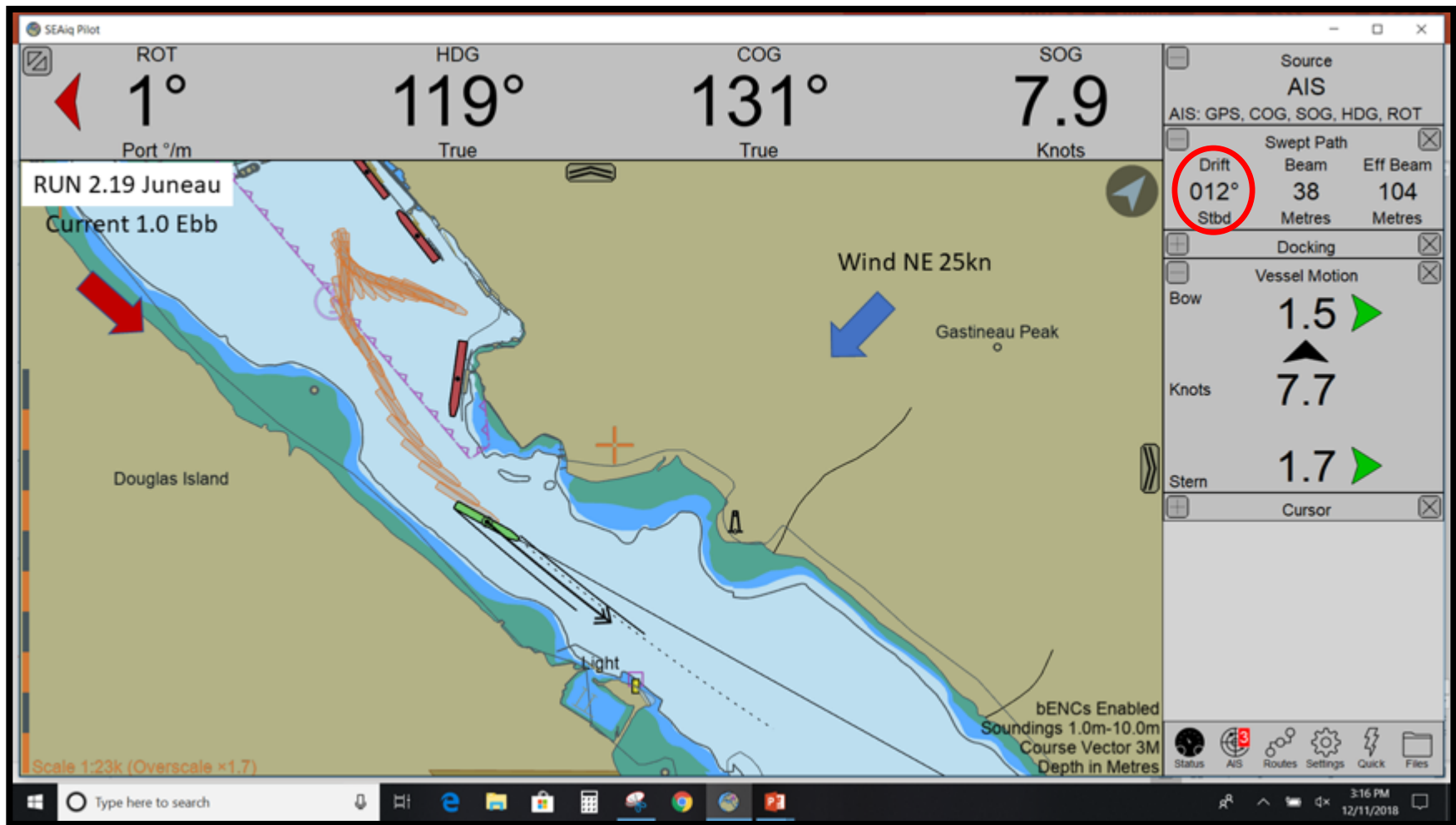
Tuesday 12/11/2018

9th Run







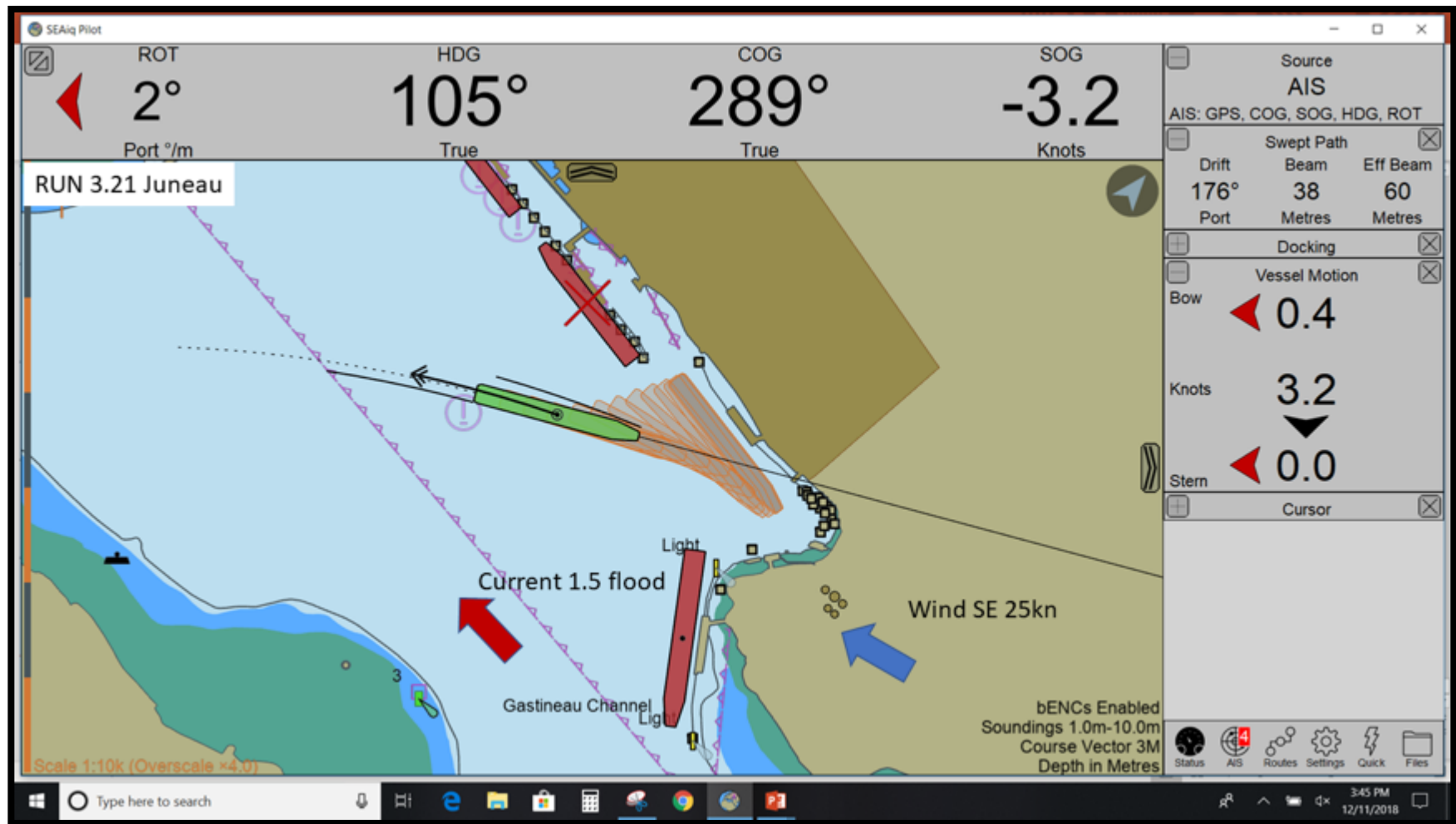


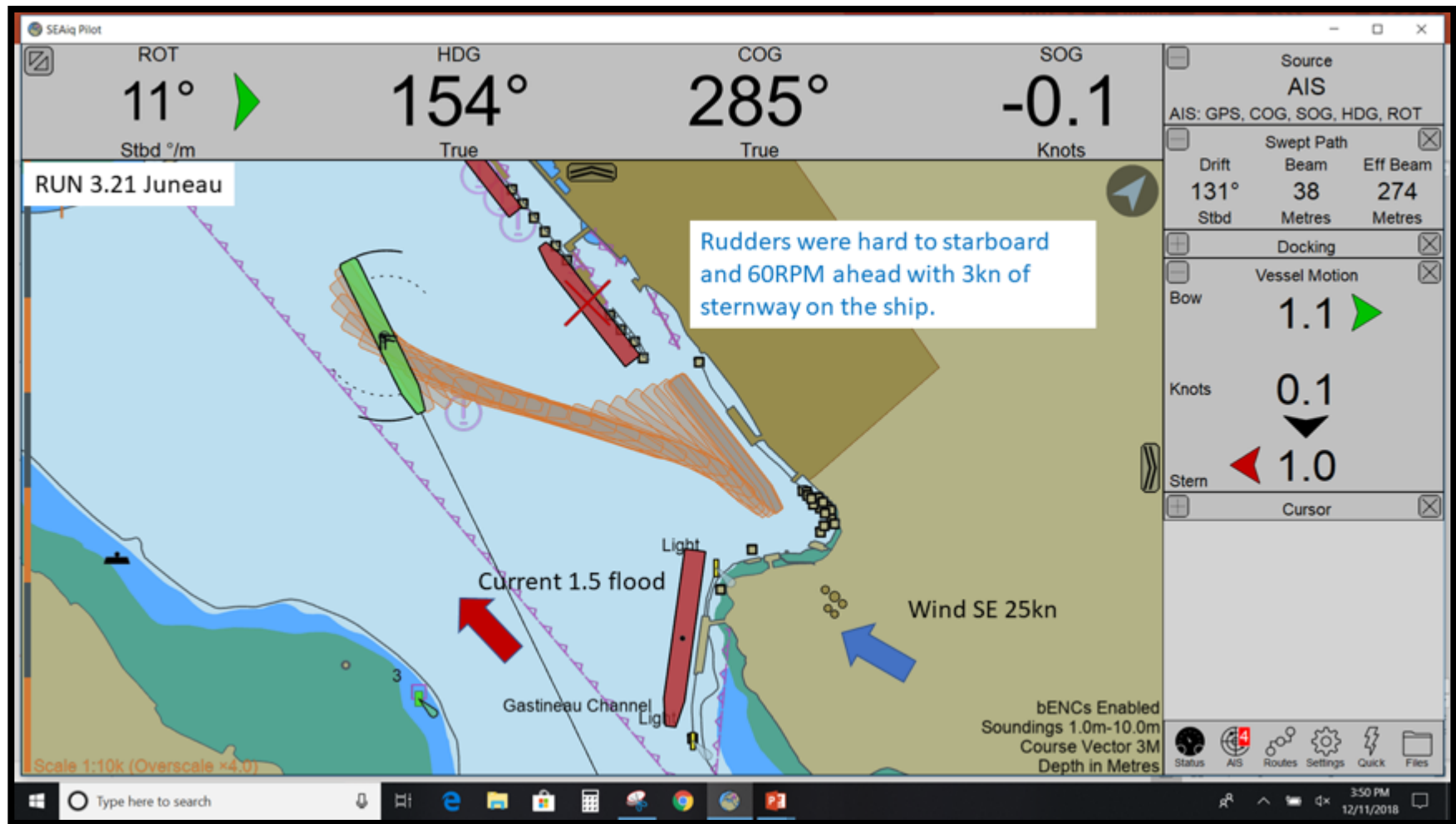
Run 3.21 Juneau, Departure, SE25, 1.5 Flood

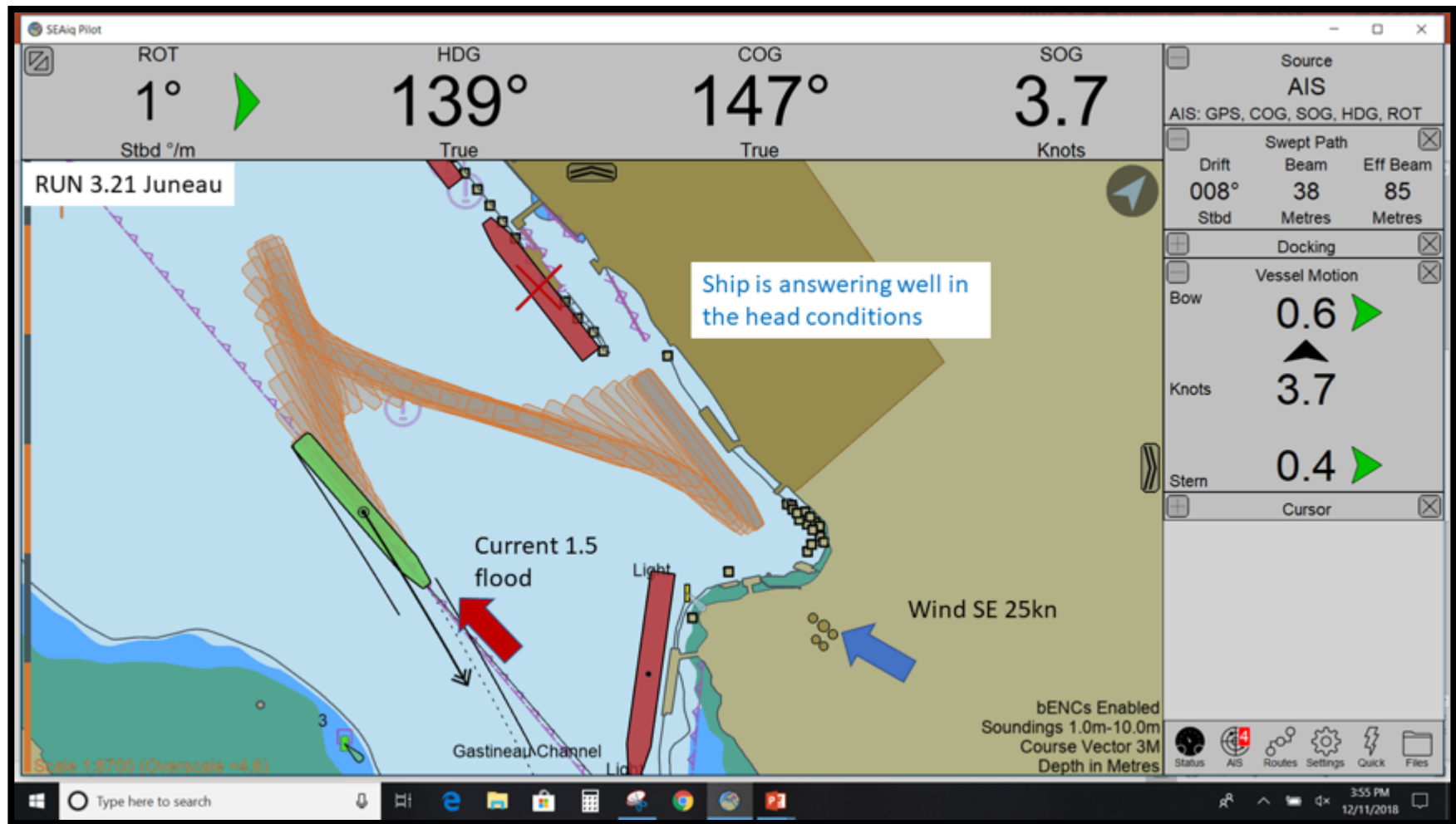
3.21 SE 25 Flood 1.5kn, Juneau Departure

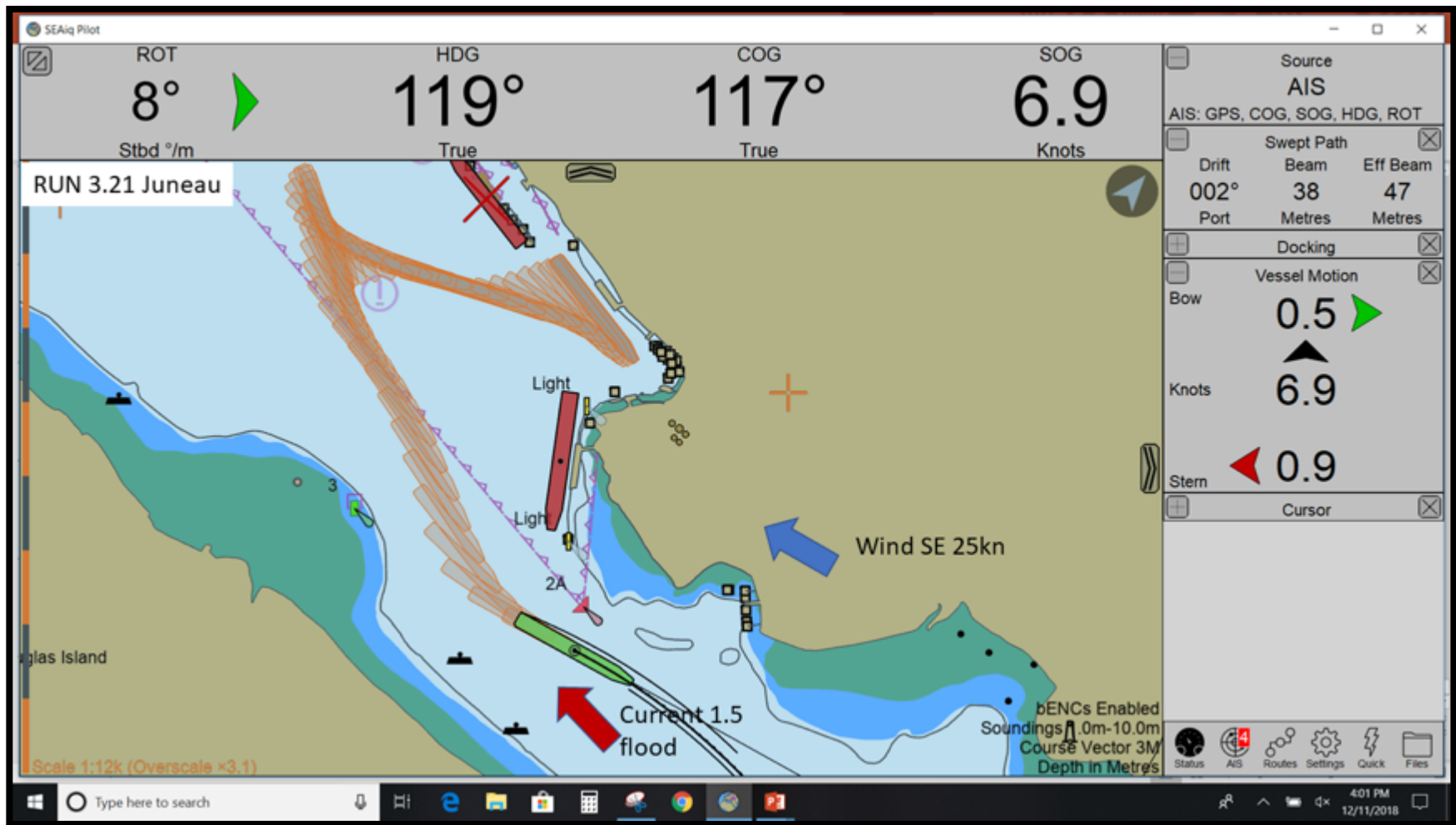
Tuesday 12/11/2018

10th Run







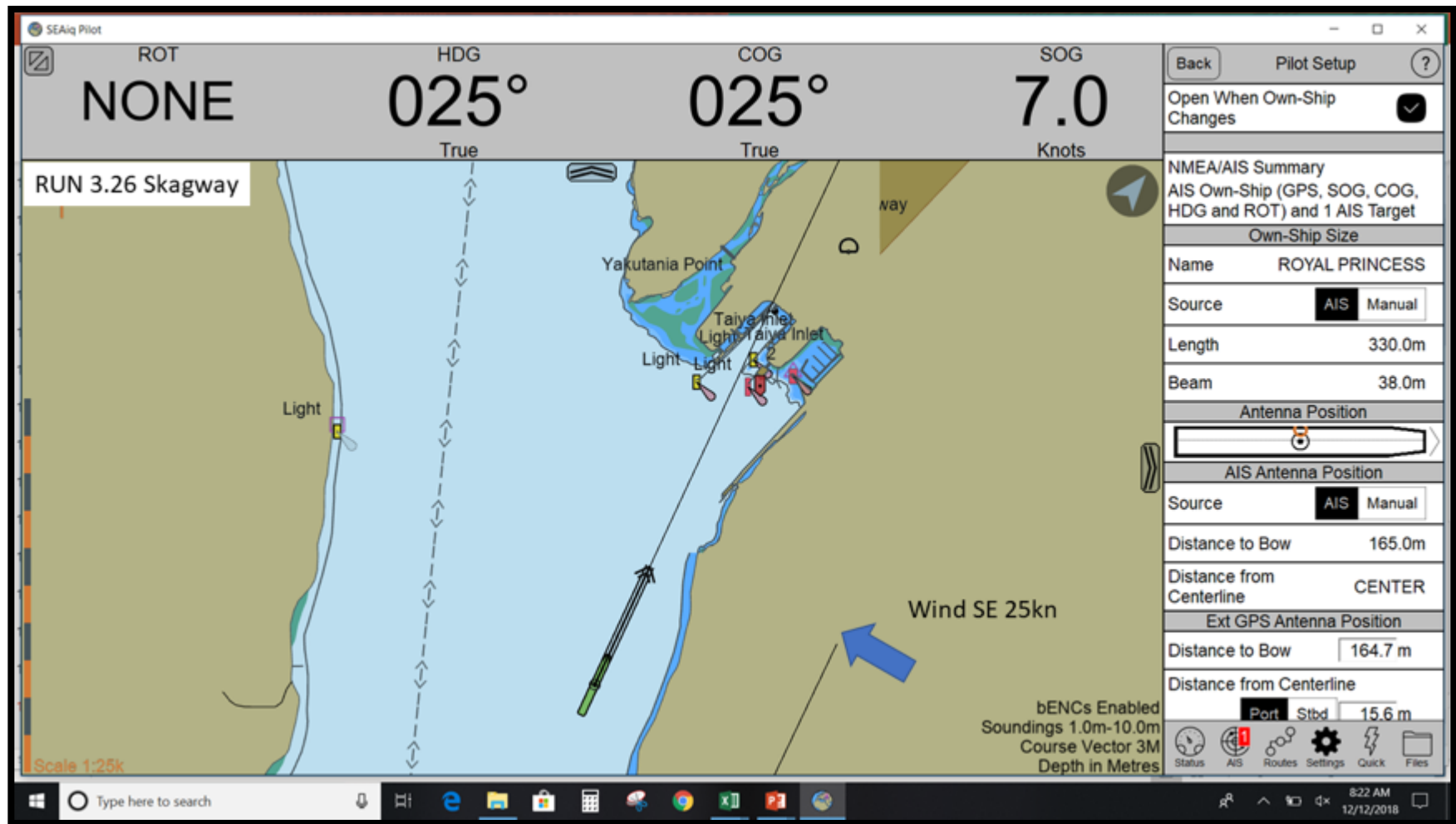


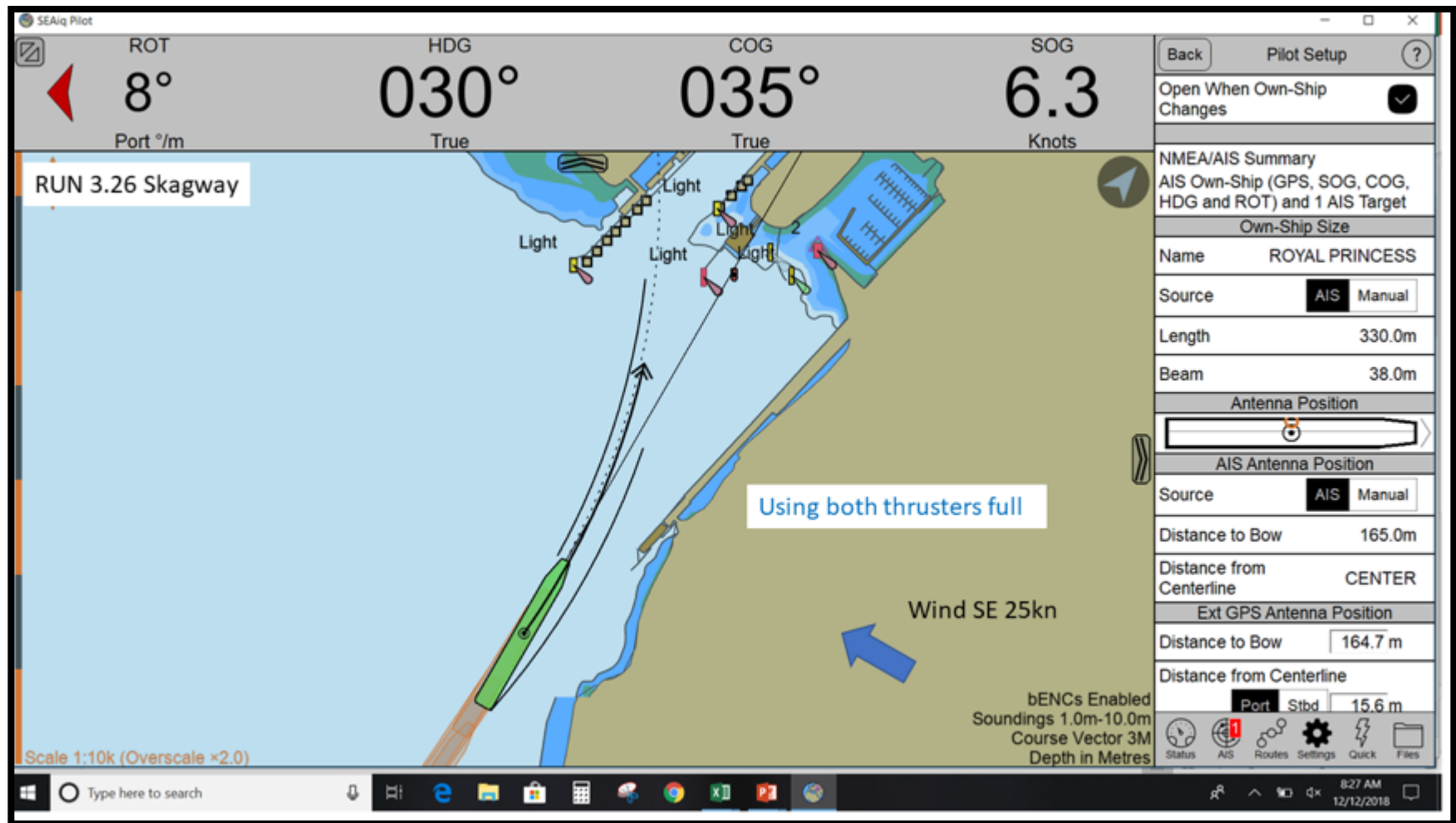
Run 3.26, Skagway, SE 25kn

3.26 SE 25kn, No Current, Skagway Arriving

Wednesday 12/12/2018

1st Run







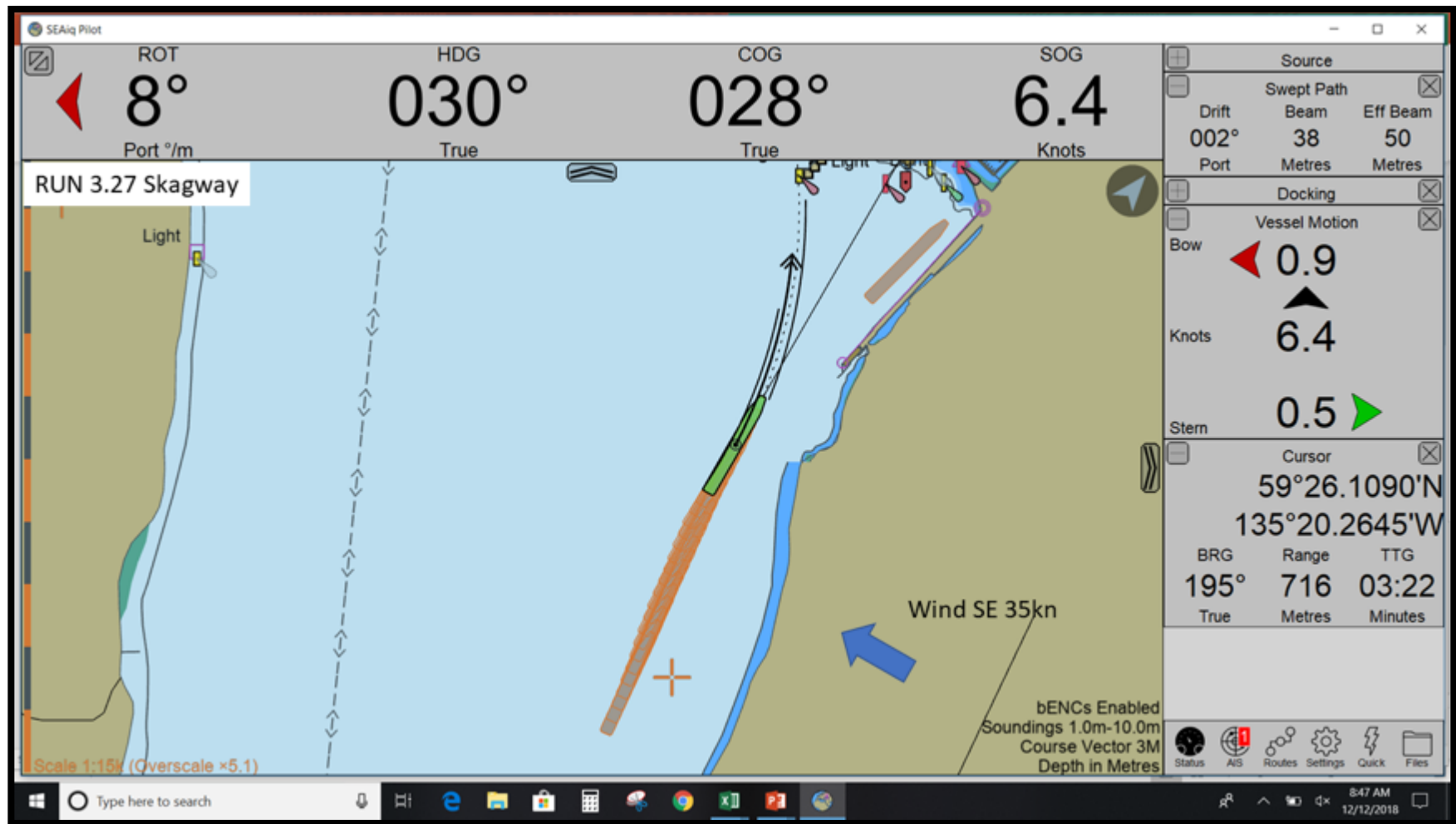


Run 3.27, Skagway, SE 35kn

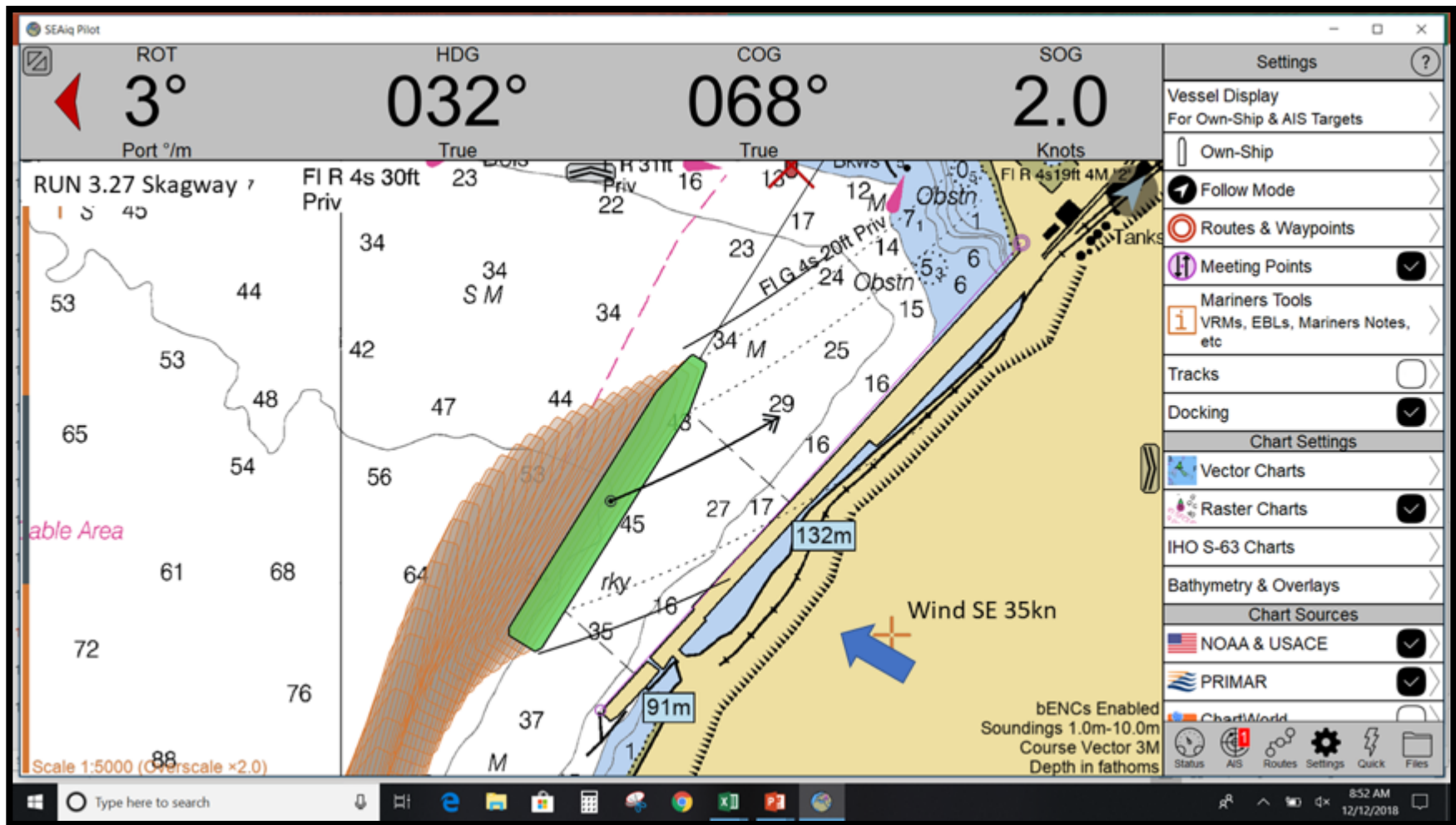
3.27 SE 35kn, No Current, Skagway Arriving

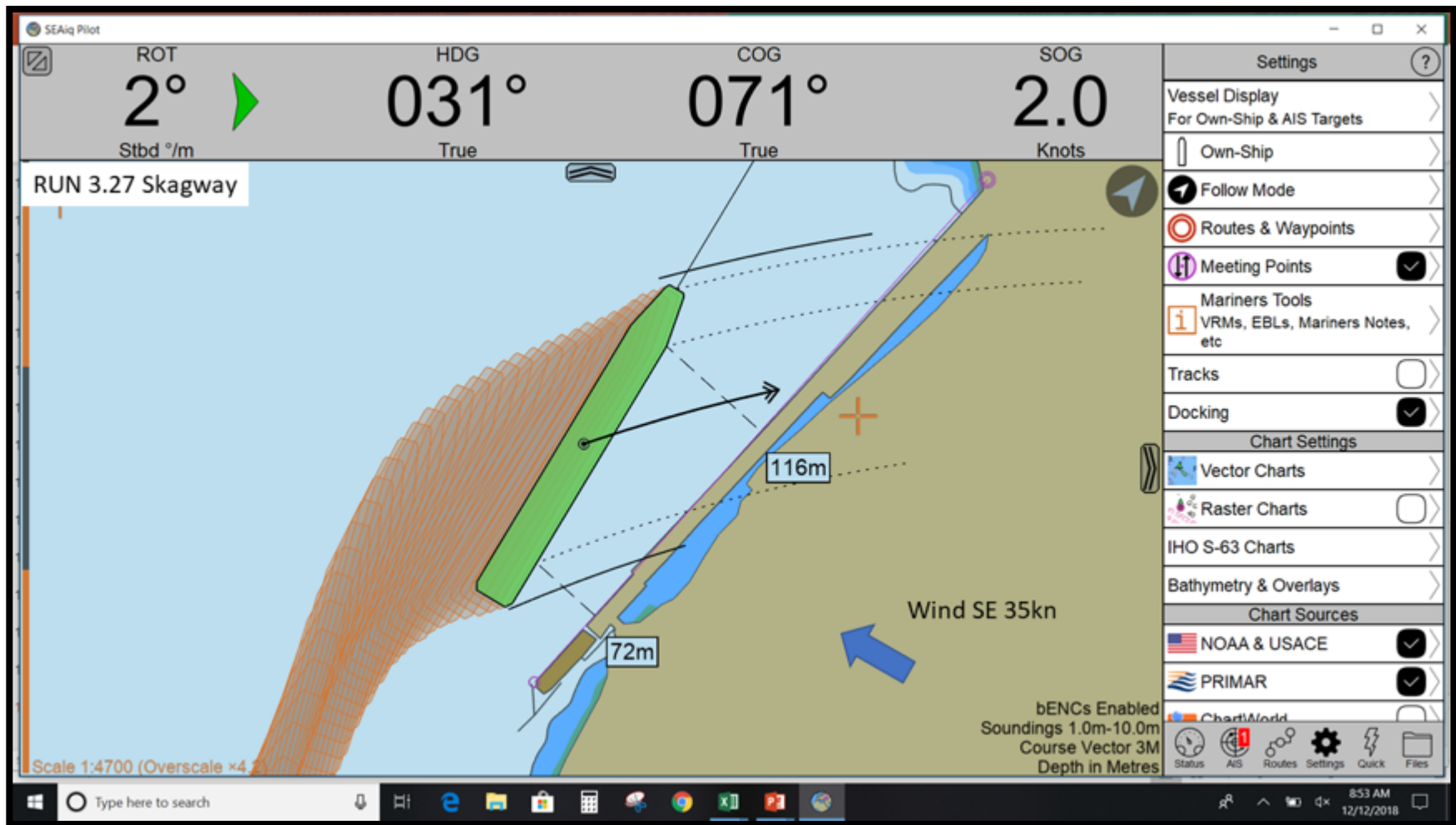
Wednesday 12/12/2018

2nd Run









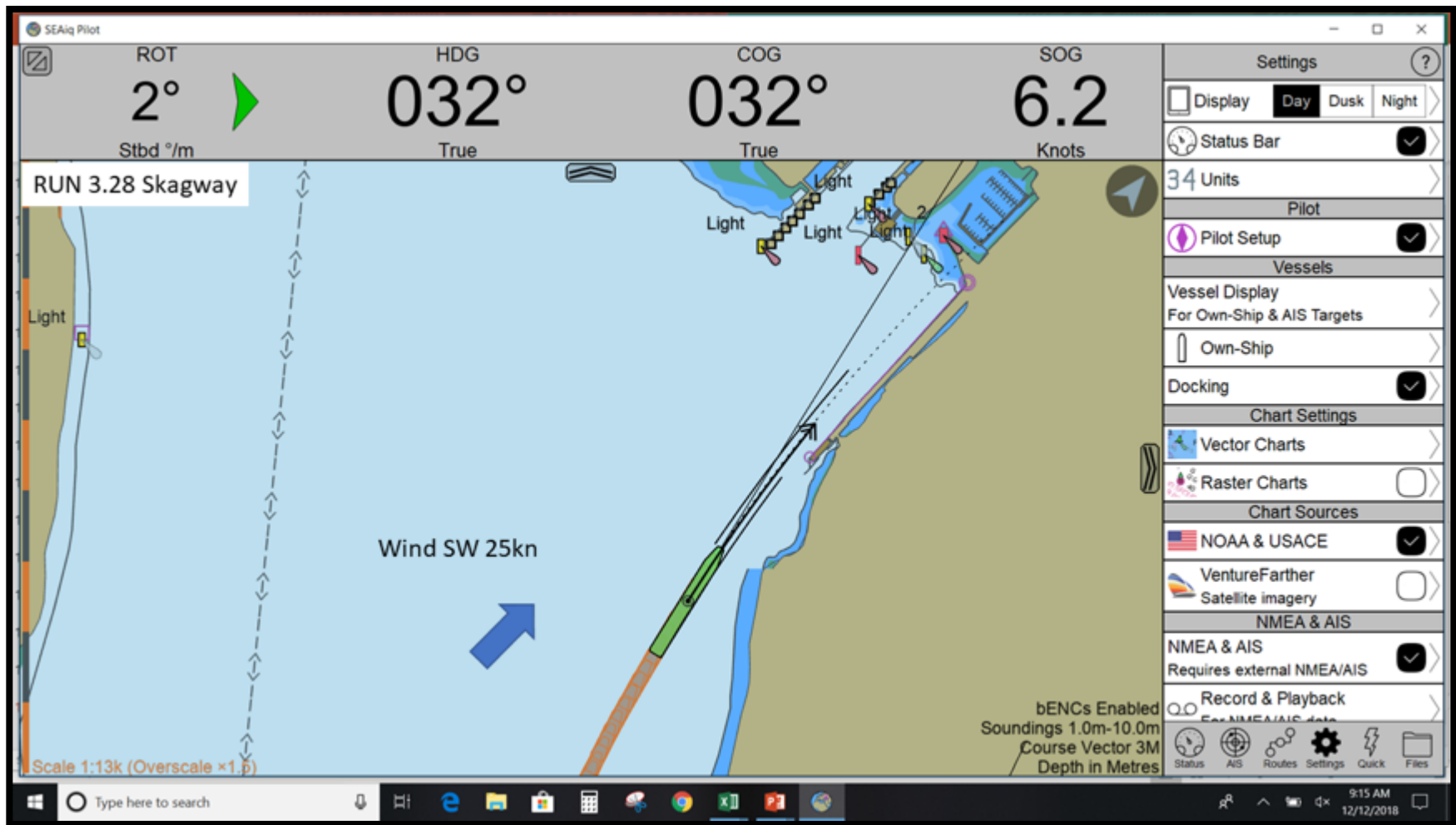


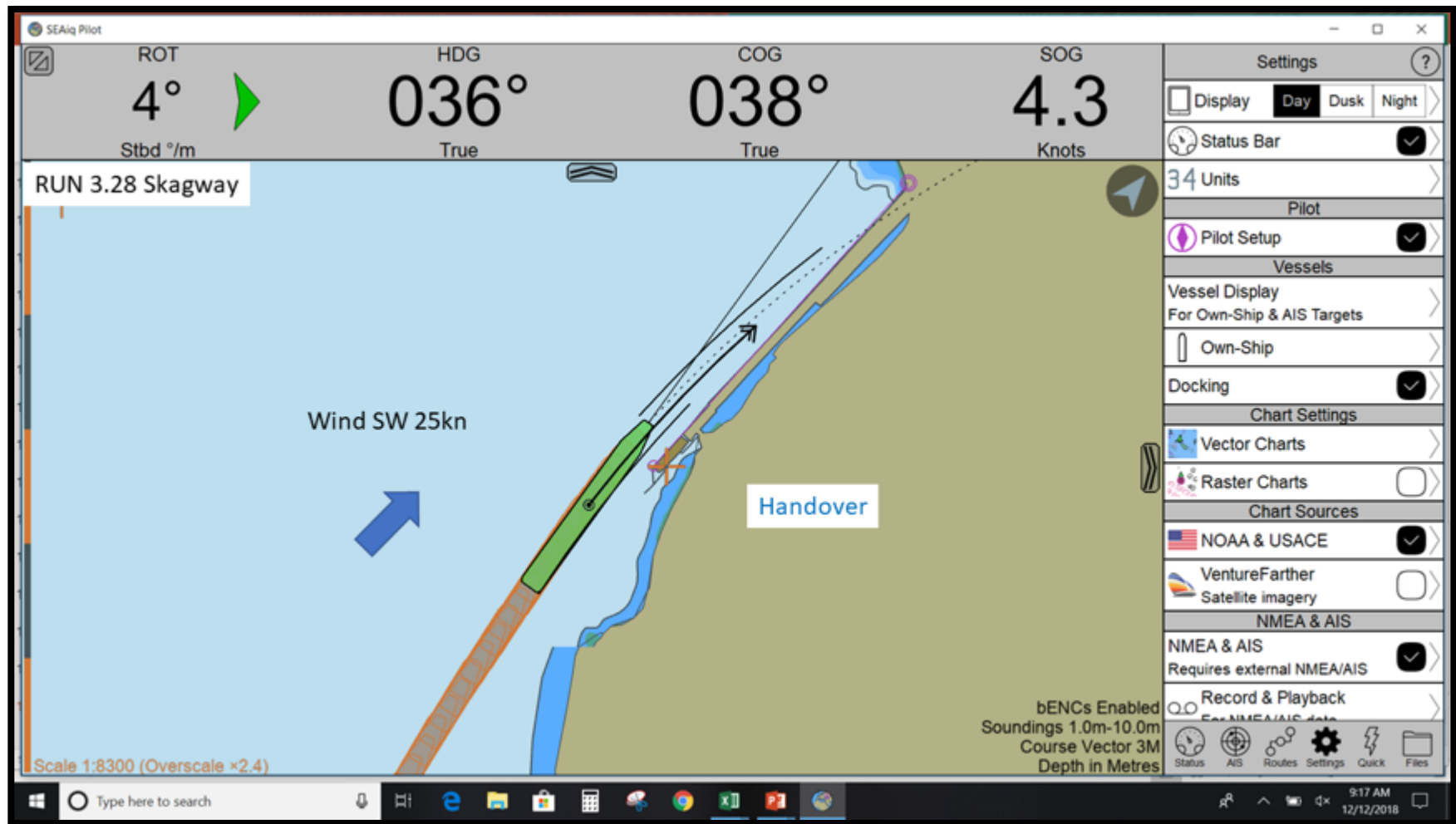
Run 3.28, Skagway, SW 25kn

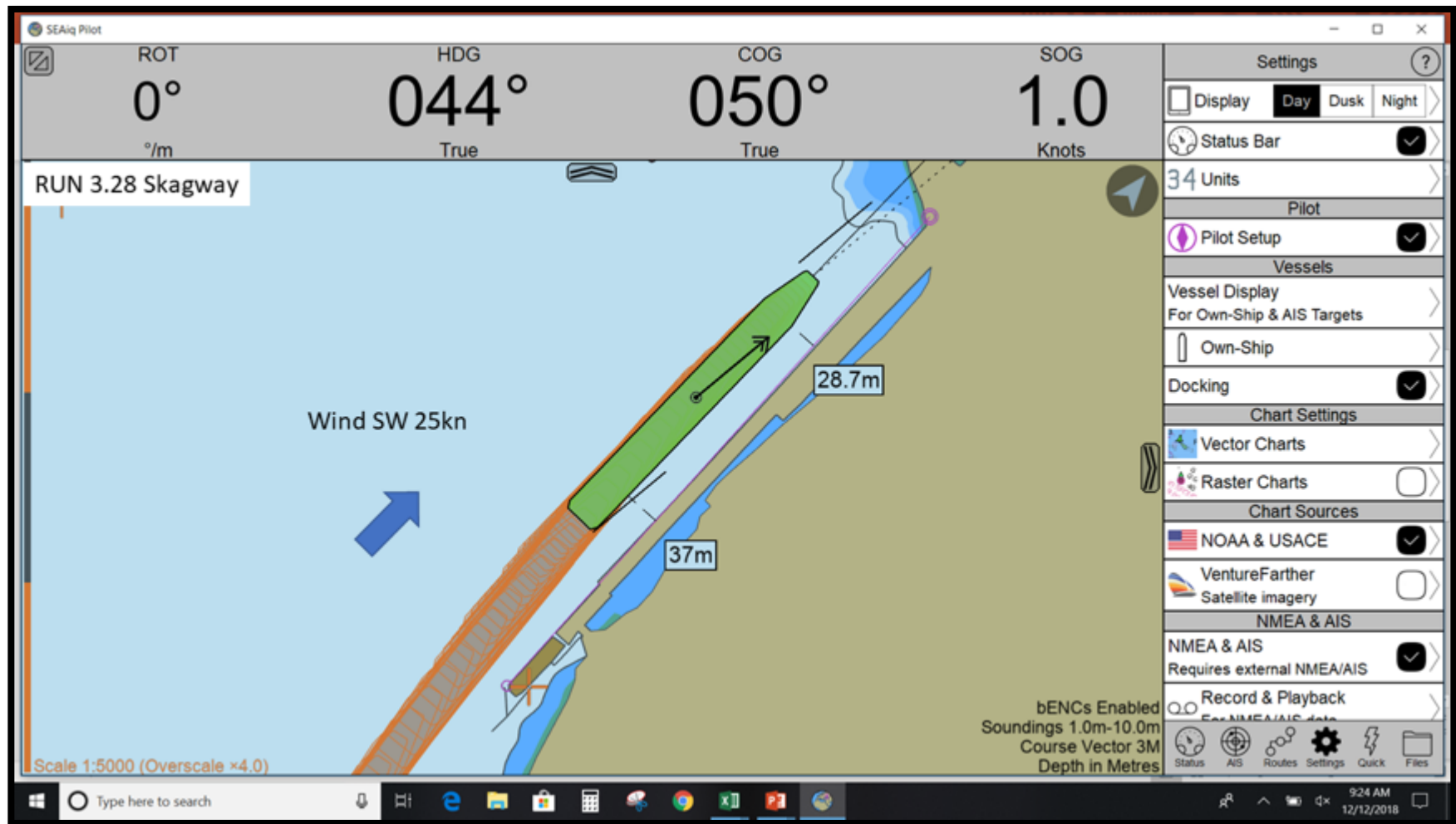
3.28 SW 25kn, No Current, Skagway Arriving

Wednesday 12/12/2018

3rd Run





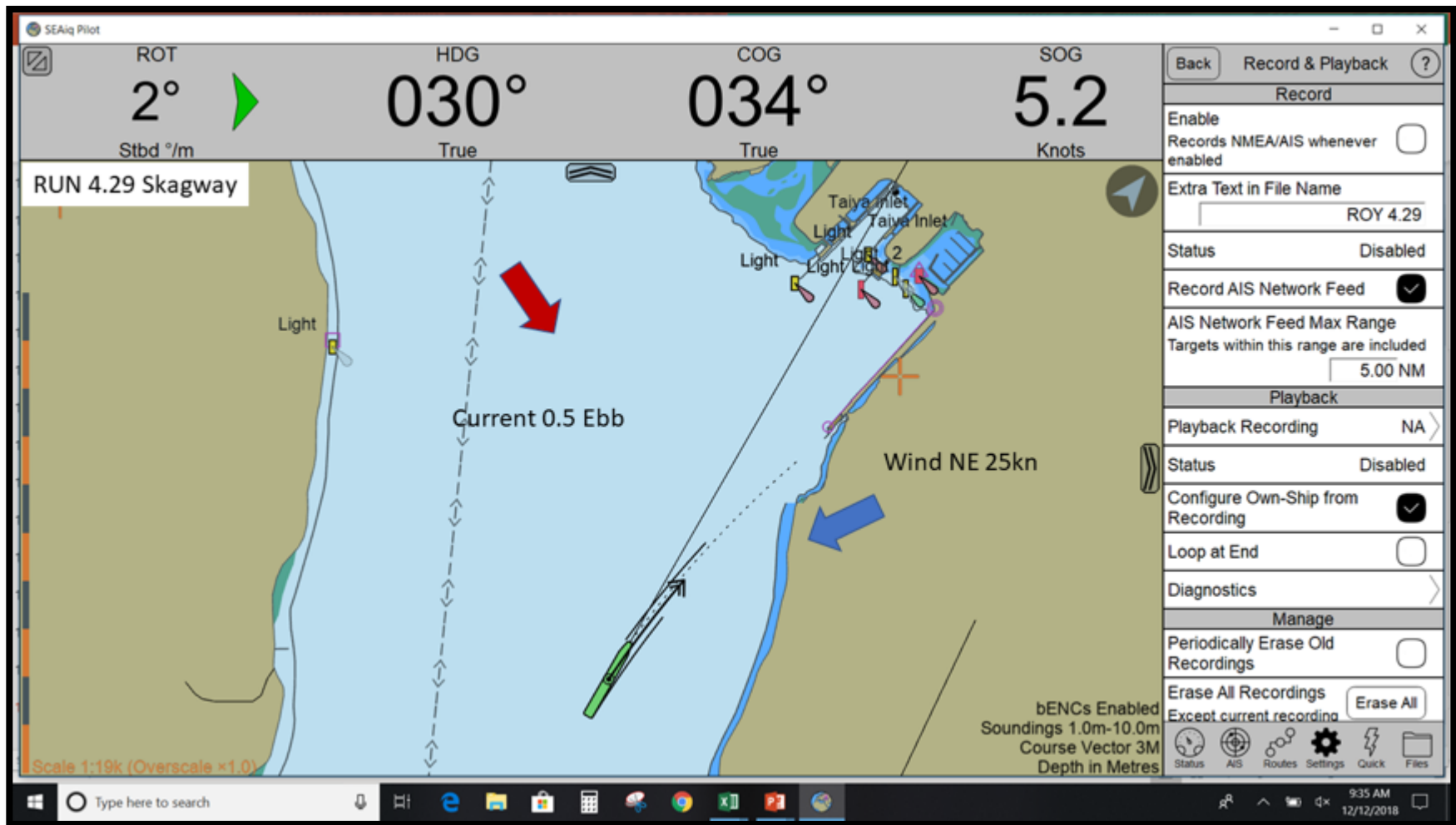


Run 4.29, Skagway, Arrival, NE 25kn

4.29 NE 25kn, 0.5 Ebb Current, Skagway Arriving

Wednesday 12/12/2018

4th Run



Run 4.41, Skagway, SW 35kn

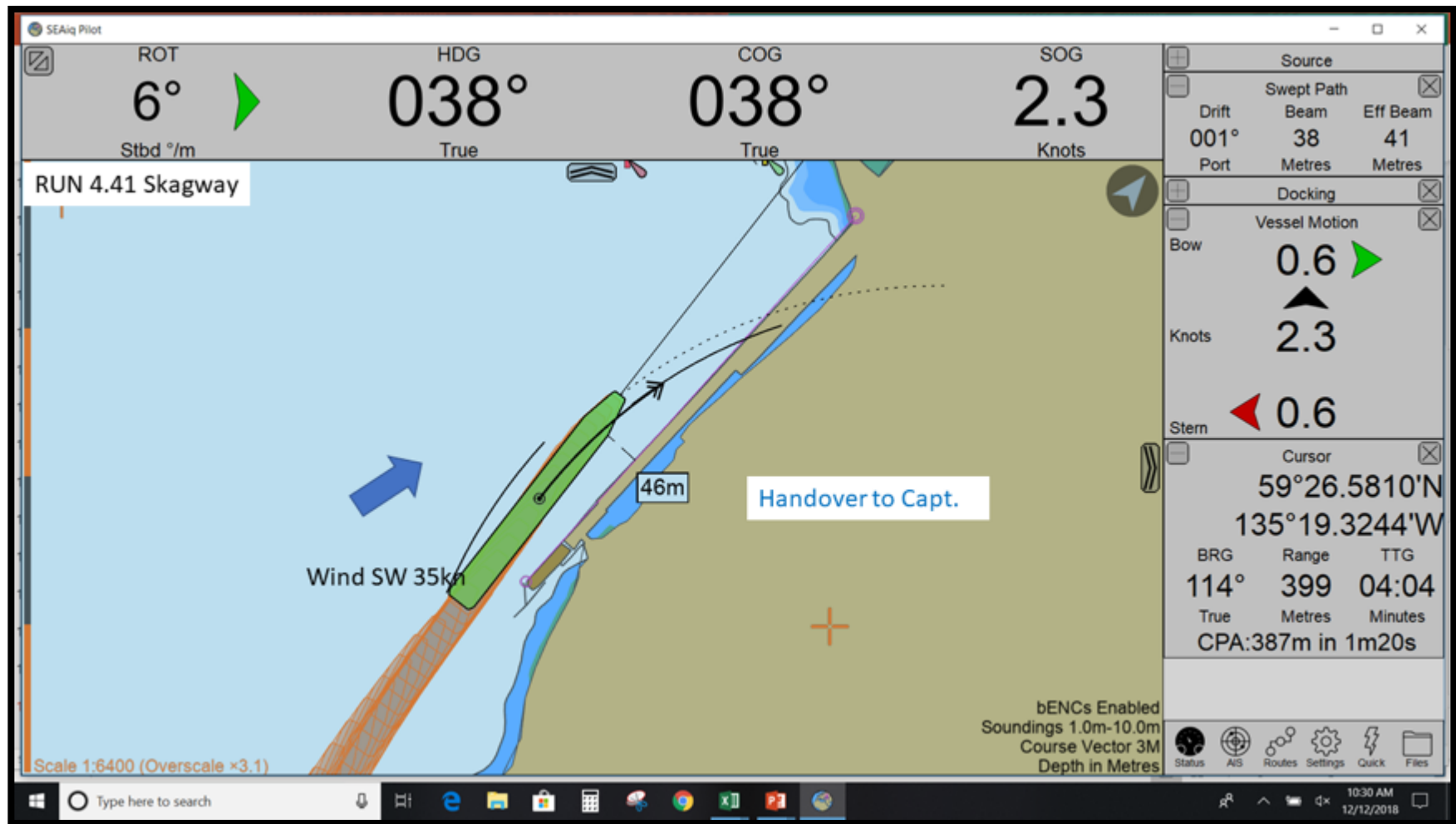
4.41 SW 35kn, Wind Driven Current, Skagway Arriving

Wednesday 12/12/2018

5th Run





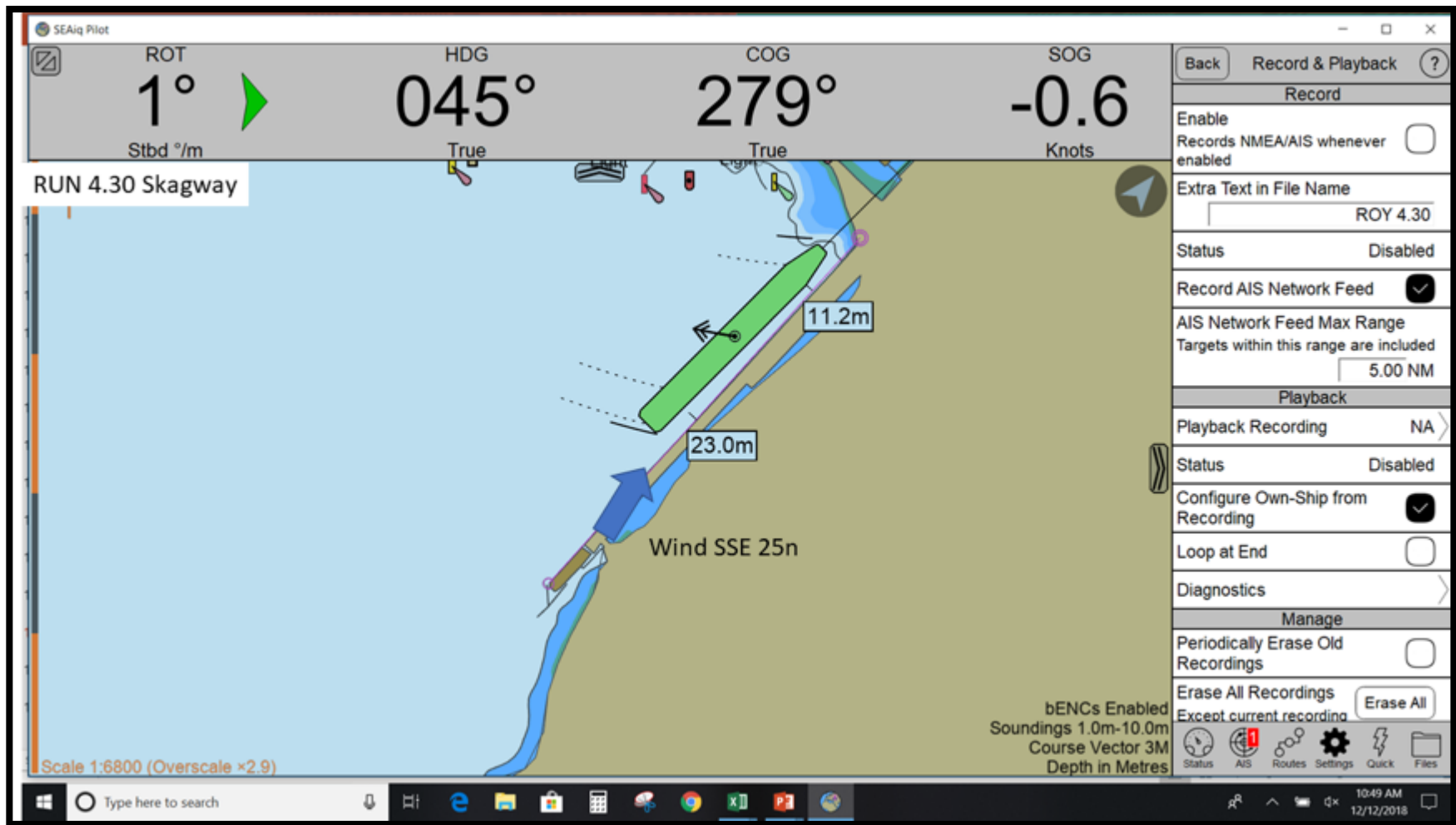


Run 4.30, Skagway, SE 25kn

4.30 SE 25kn, No Current, Skagway Departure

Wednesday 12/12/2018

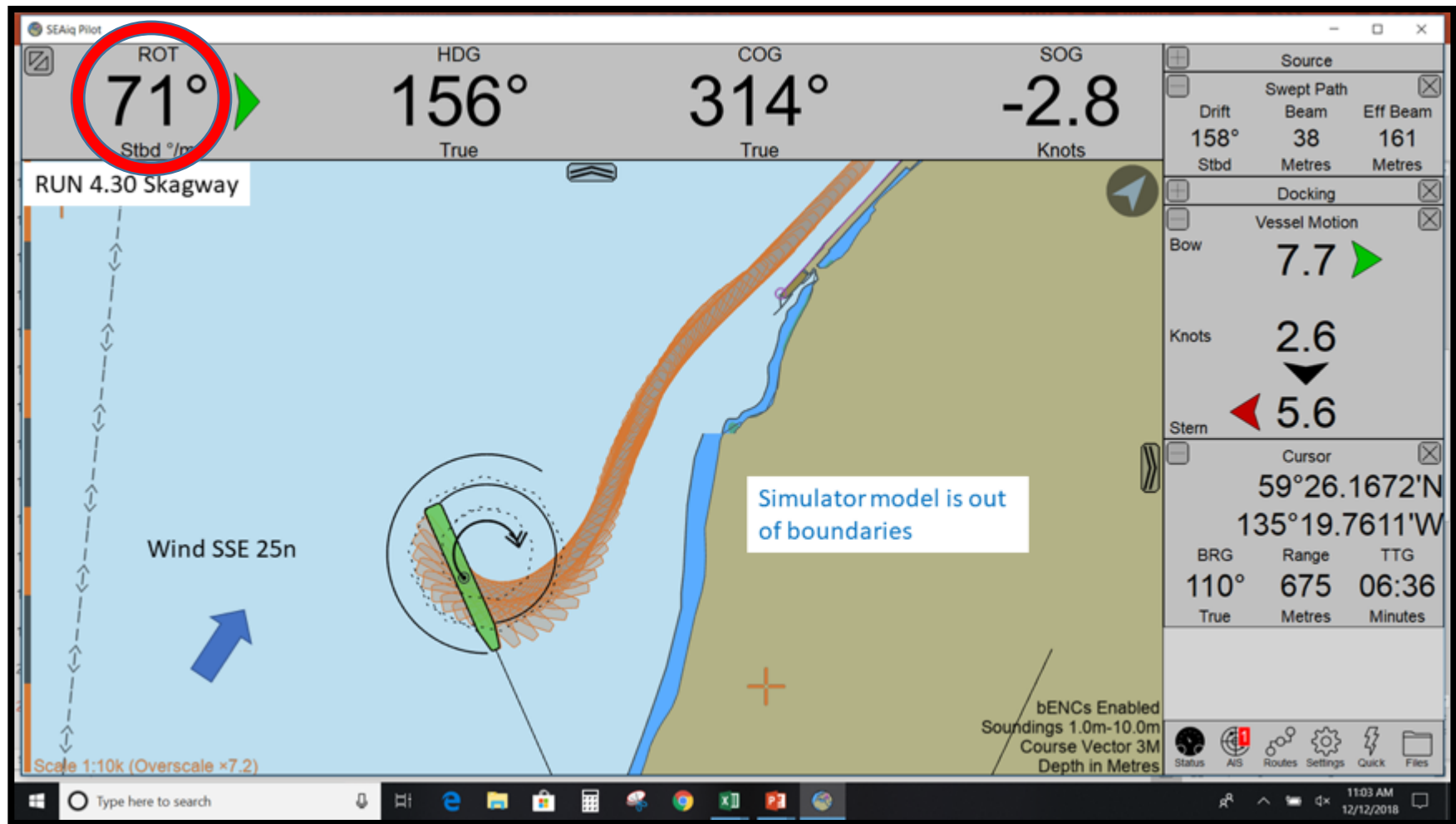
6th Run











Run 4.31, Skagway, Departure, NE35kn, 1kn Ebb

4.31 NE 35kn, Ebb 1kn Current, Skagway Departure

Wednesday 12/12/2018

7th Run

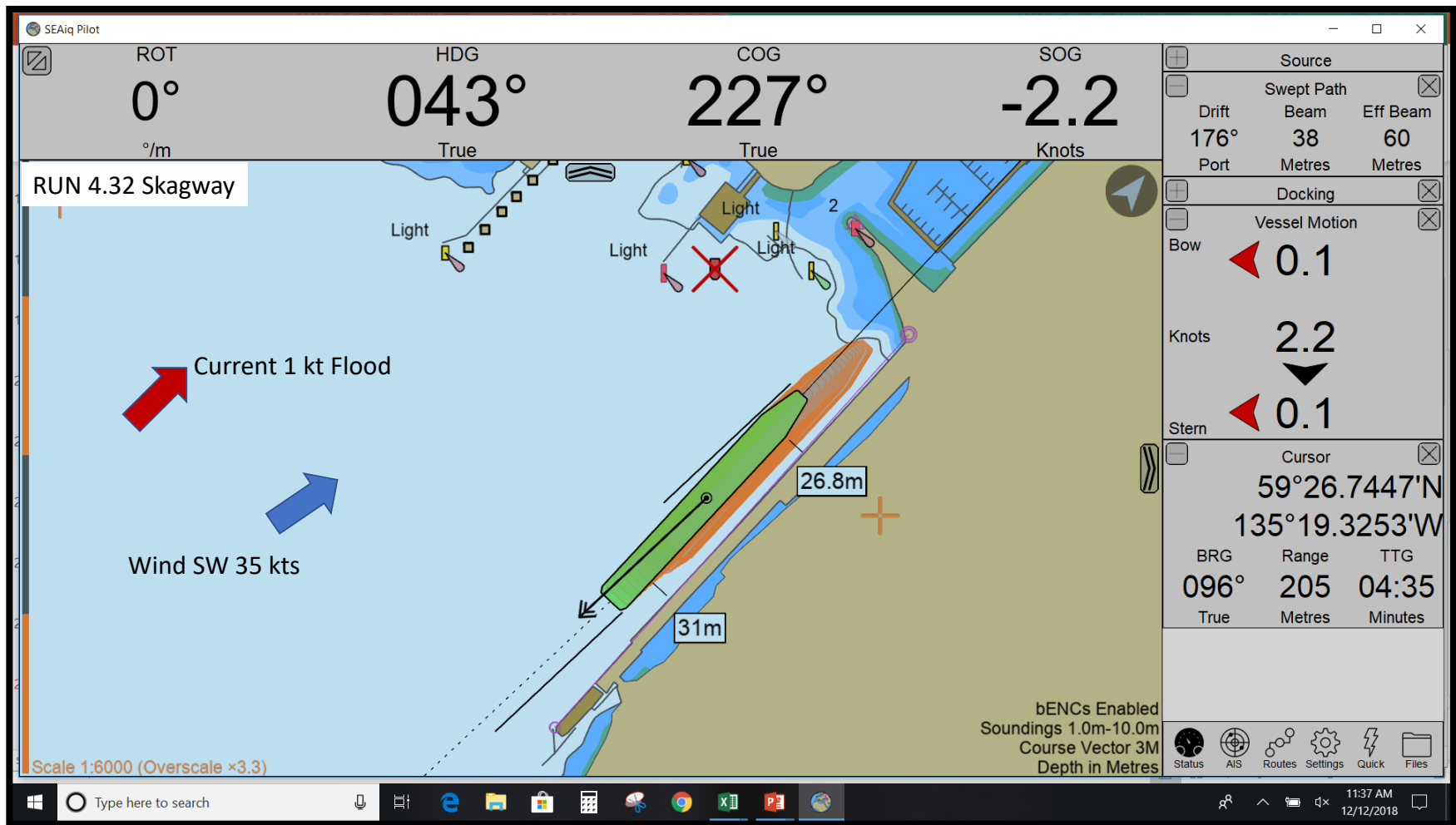


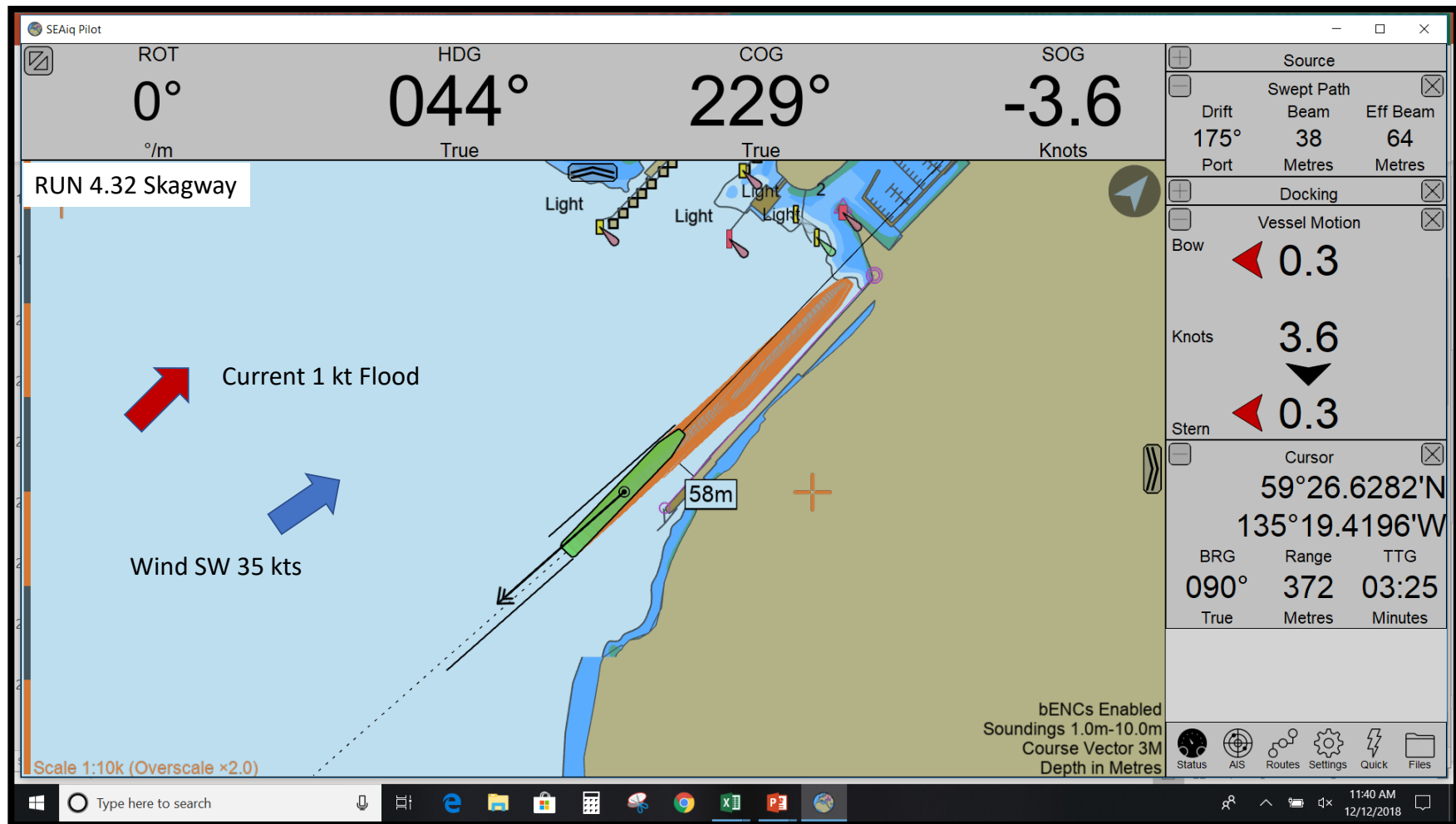
Run 4.32, Skagway, Departure, SW 35, 1kn Flood

4.32 SW 35kn, Flood 1kn Current, Skagway Departure

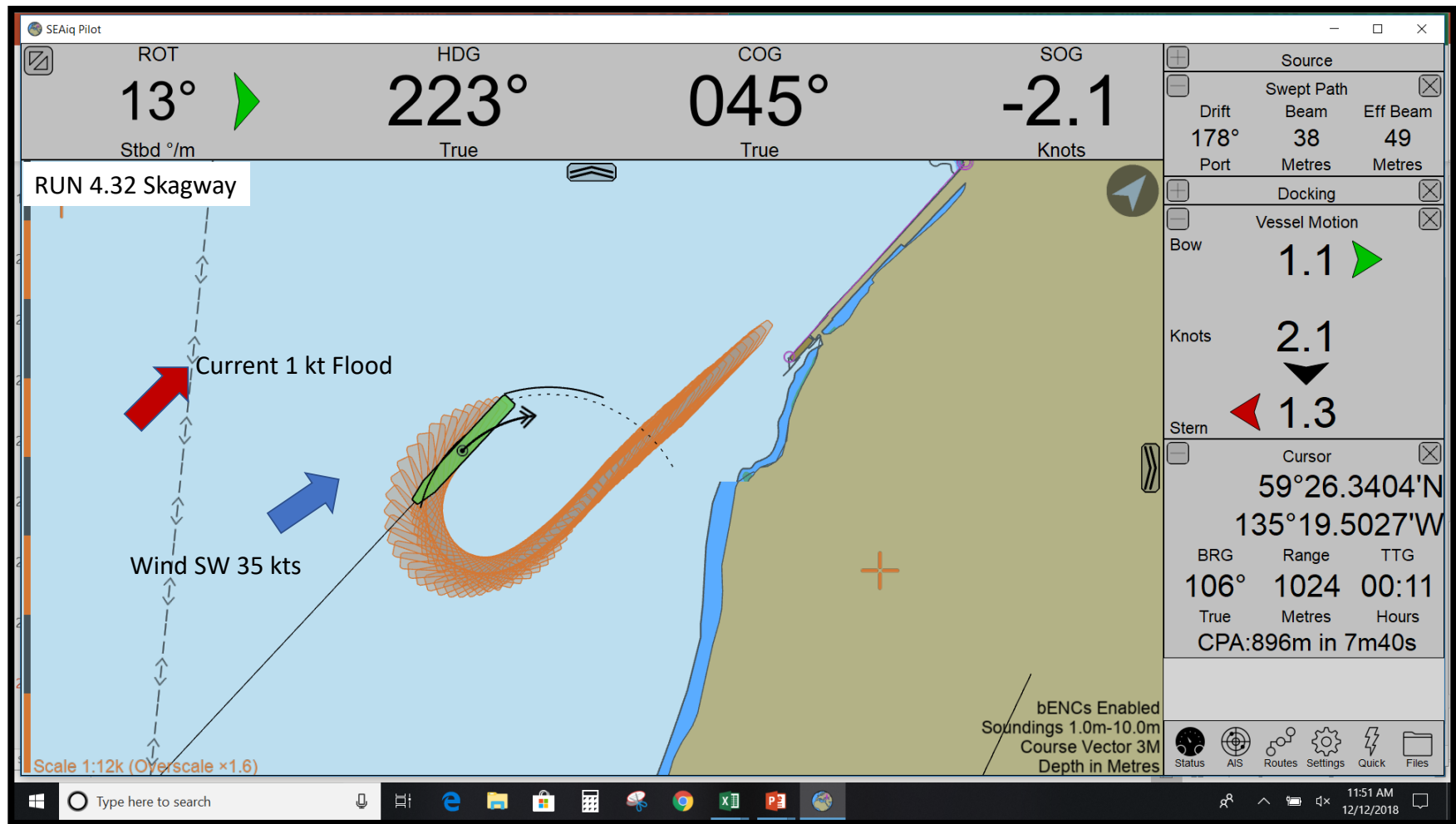
Wednesday 12/12/2018

8th Run,





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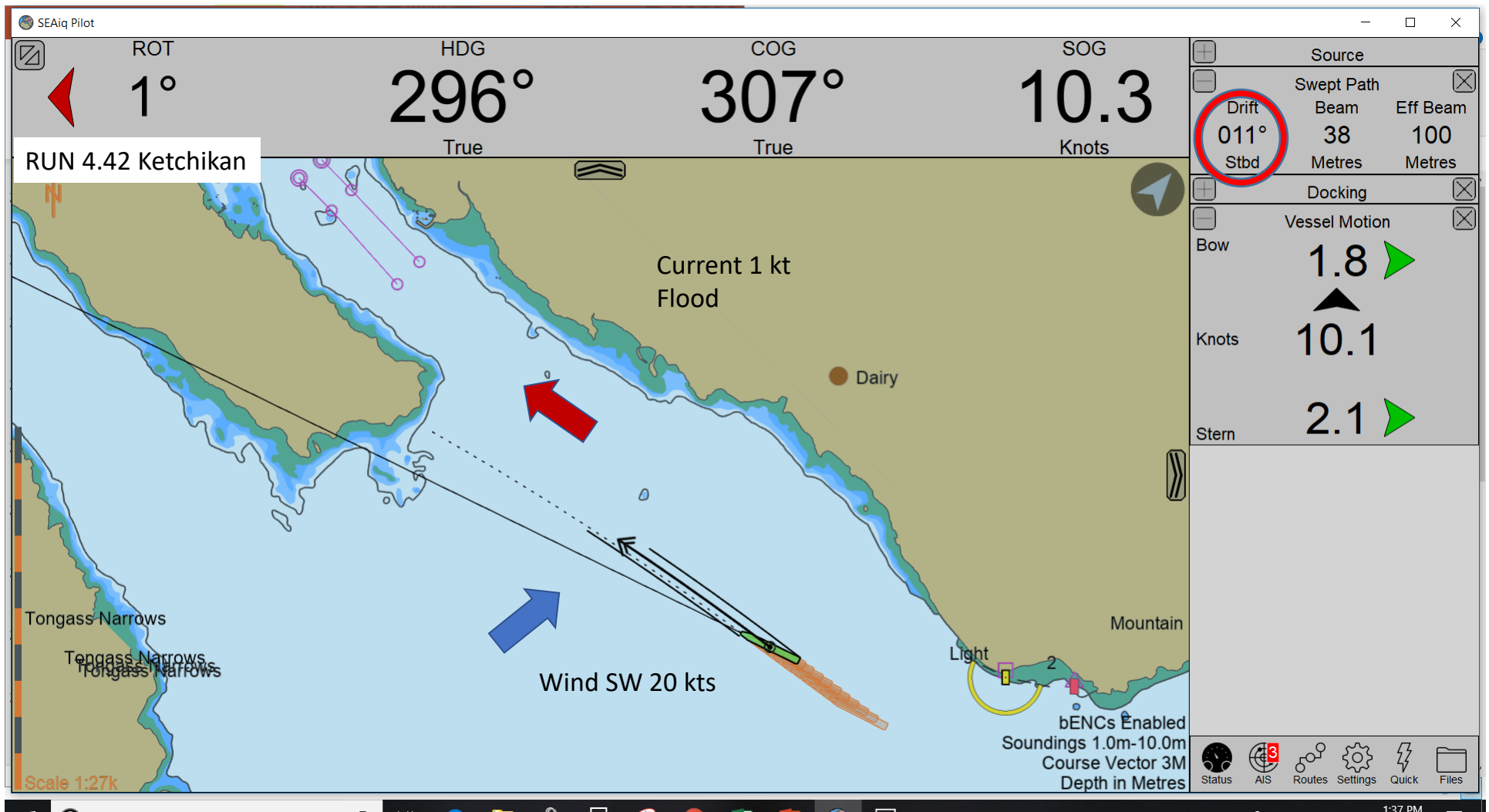


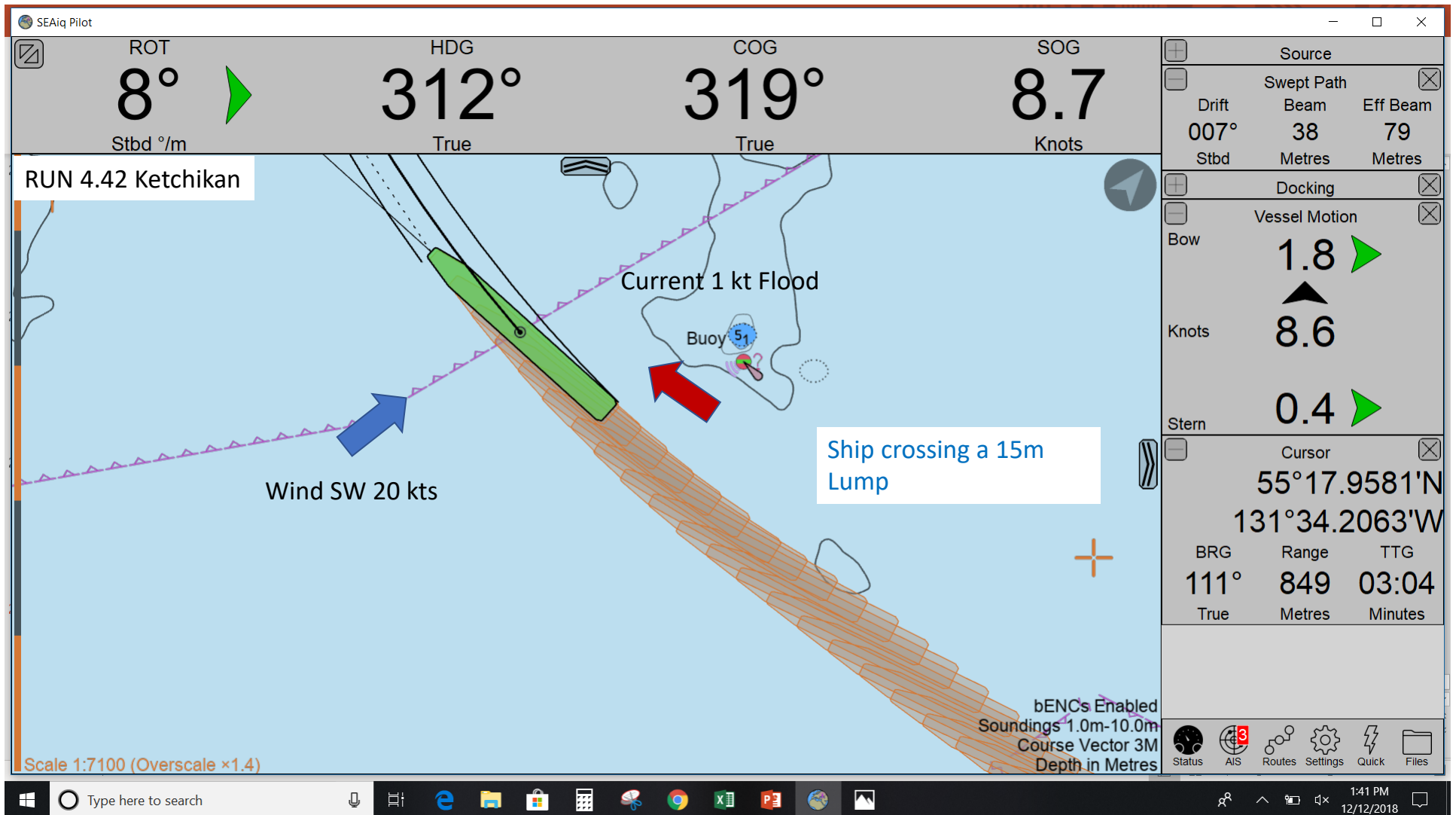
Run 4.42, Ketchikan, Arrival, SW 20 Kts, 1kn Flood

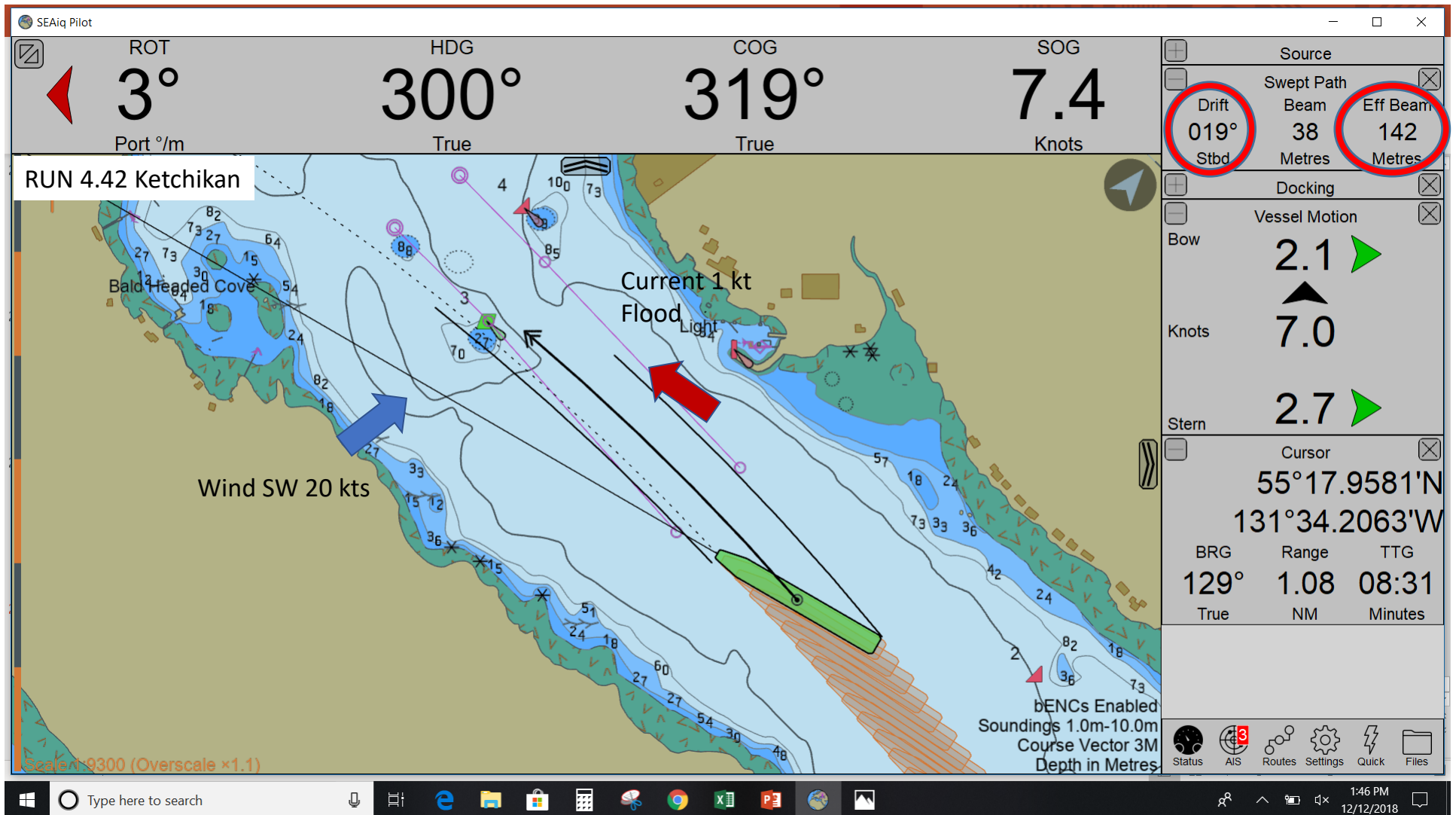
4.42 SW 20 kn, Flood 1kn Current, Ketchikan Arrival

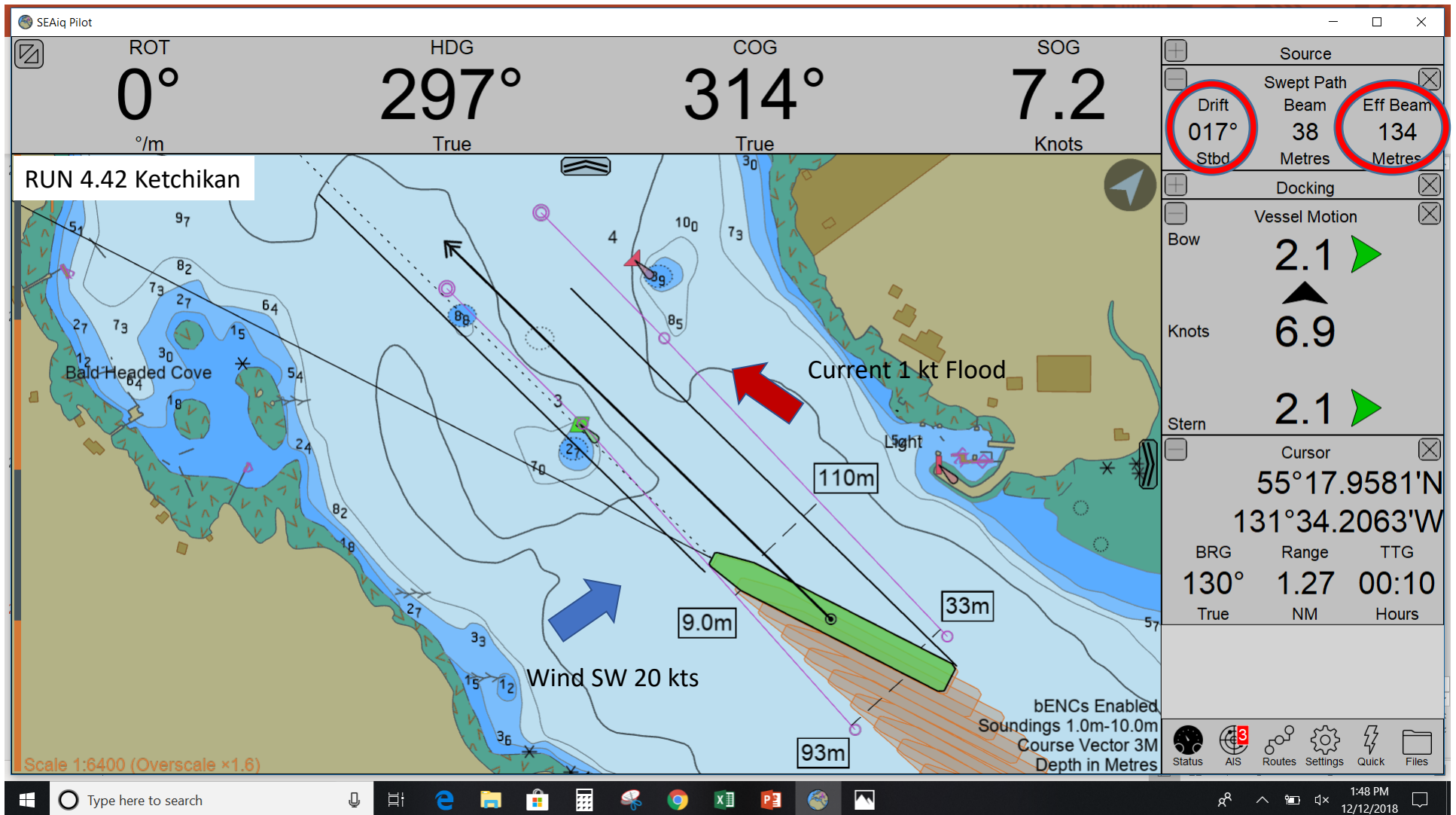
Wednesday 12/12/2018

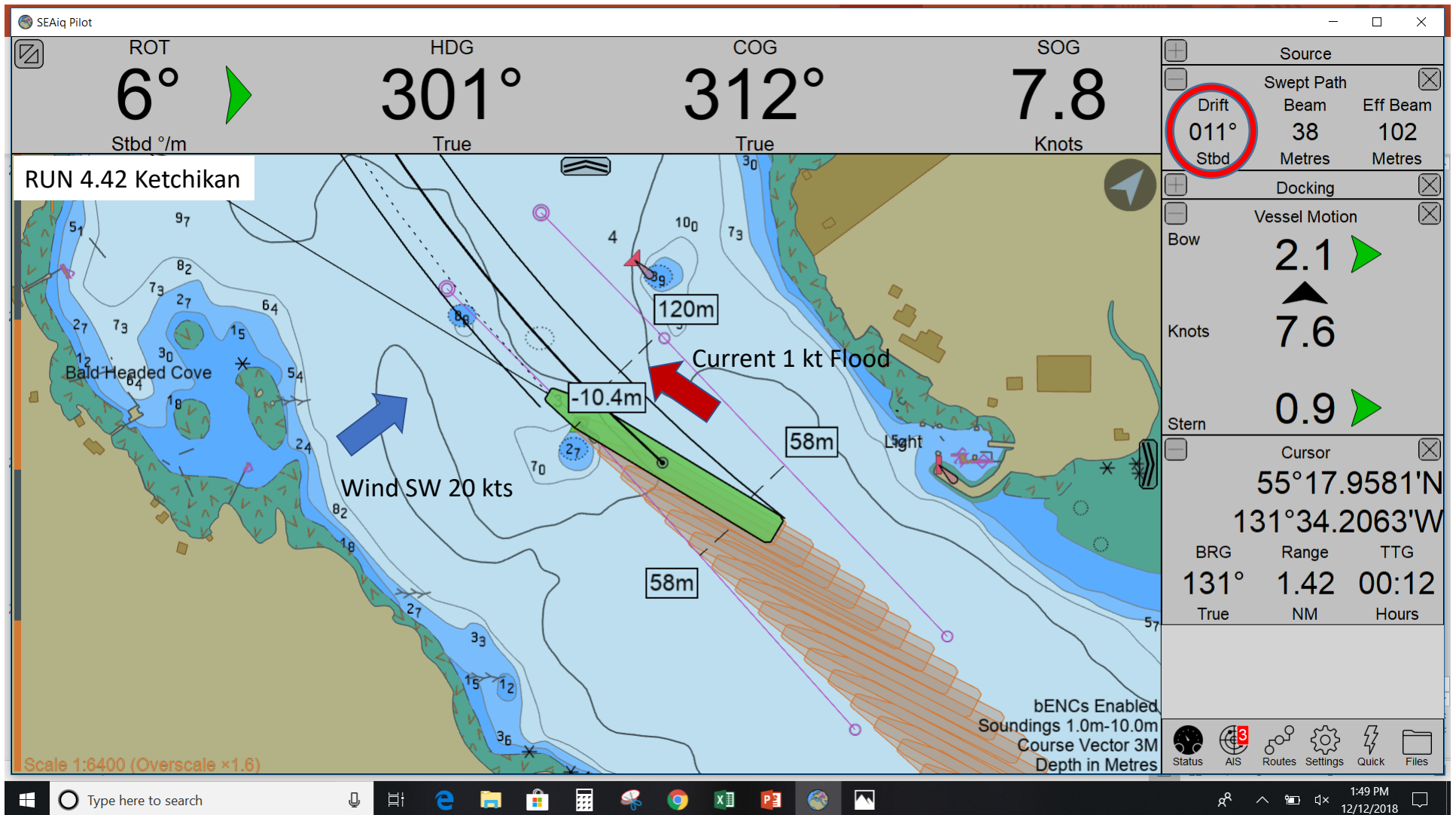
9th Run









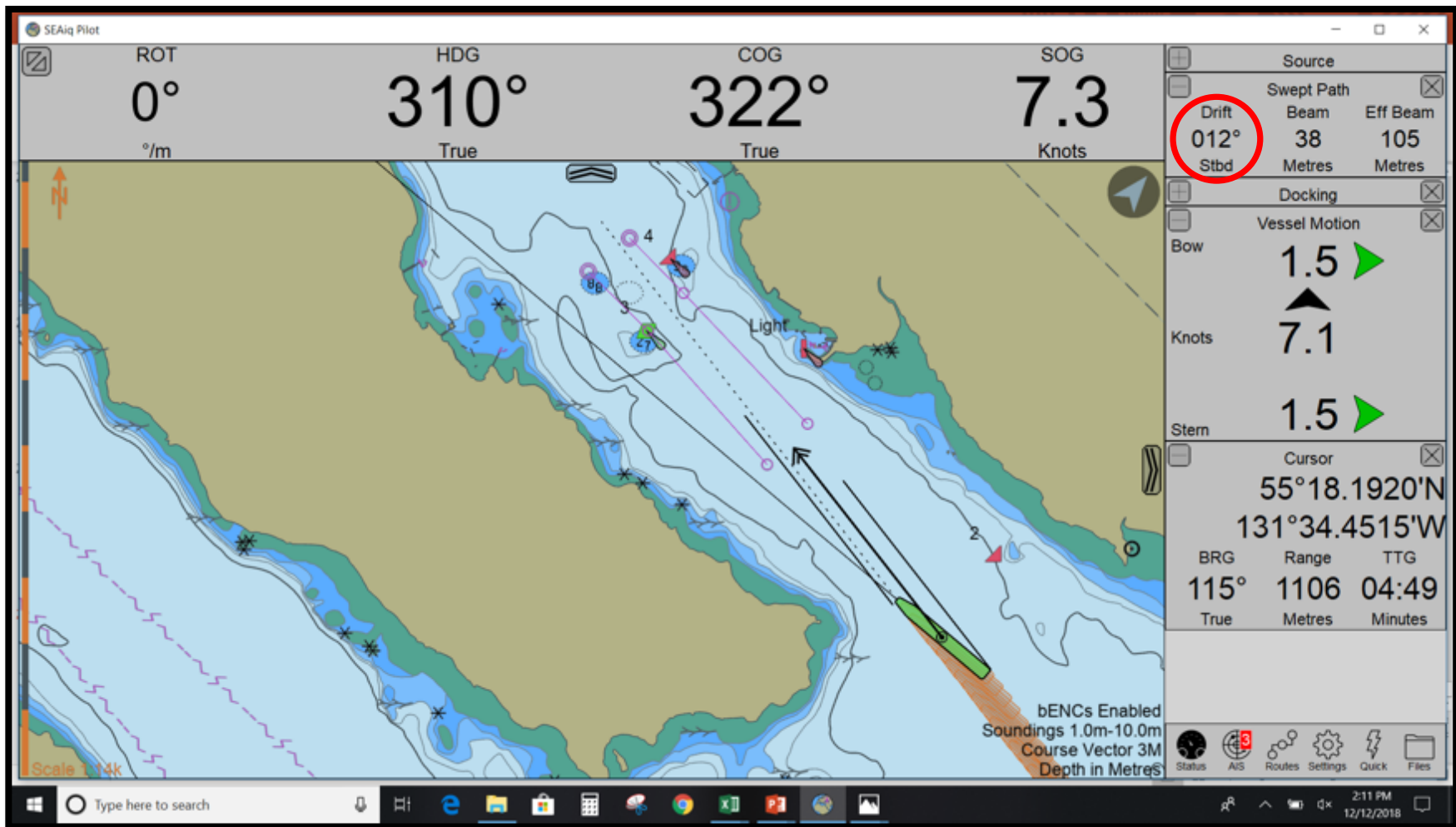


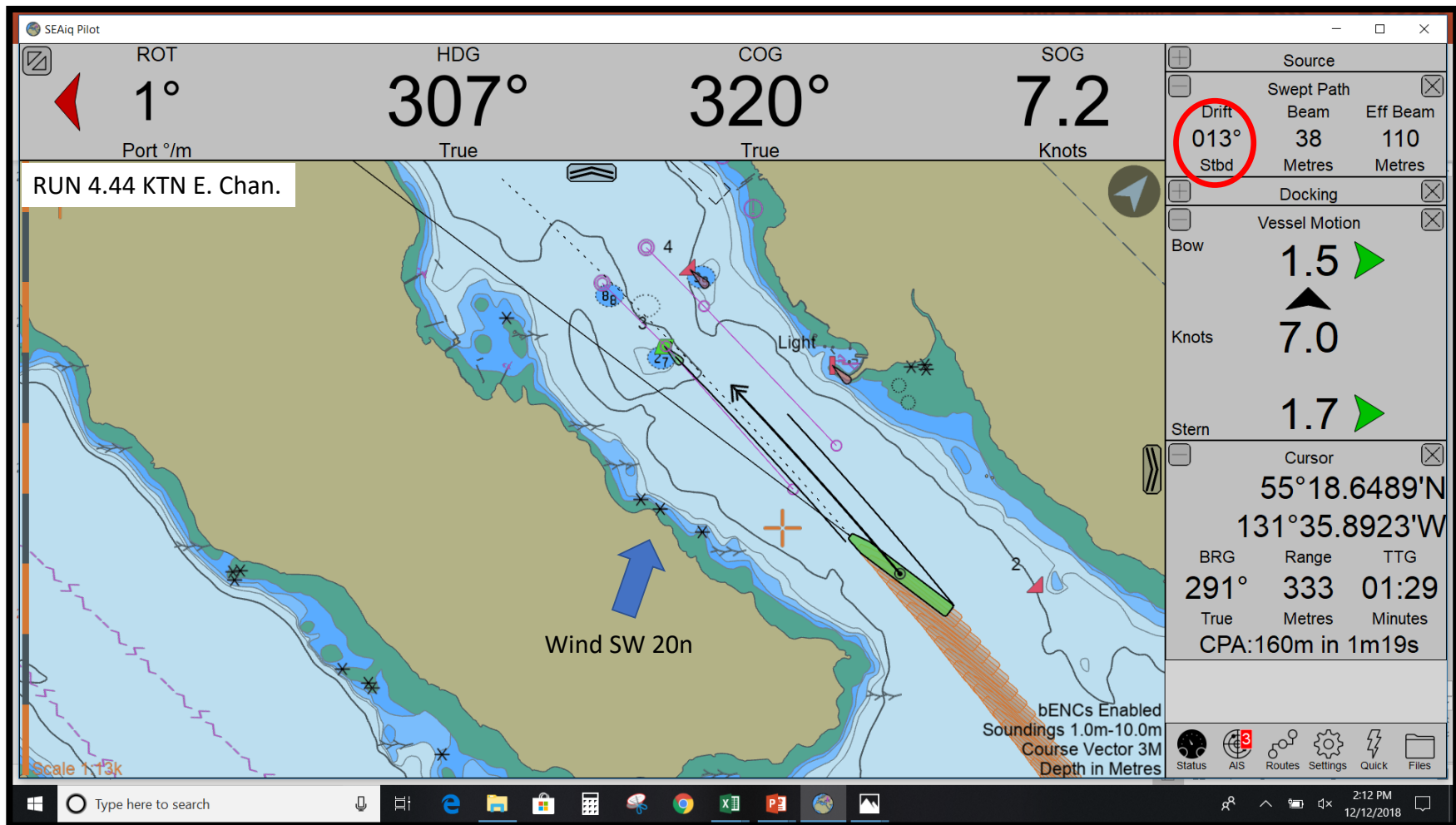
Run 4.44, Ketchikan, ECH, SW 20kn, 1kn Flood

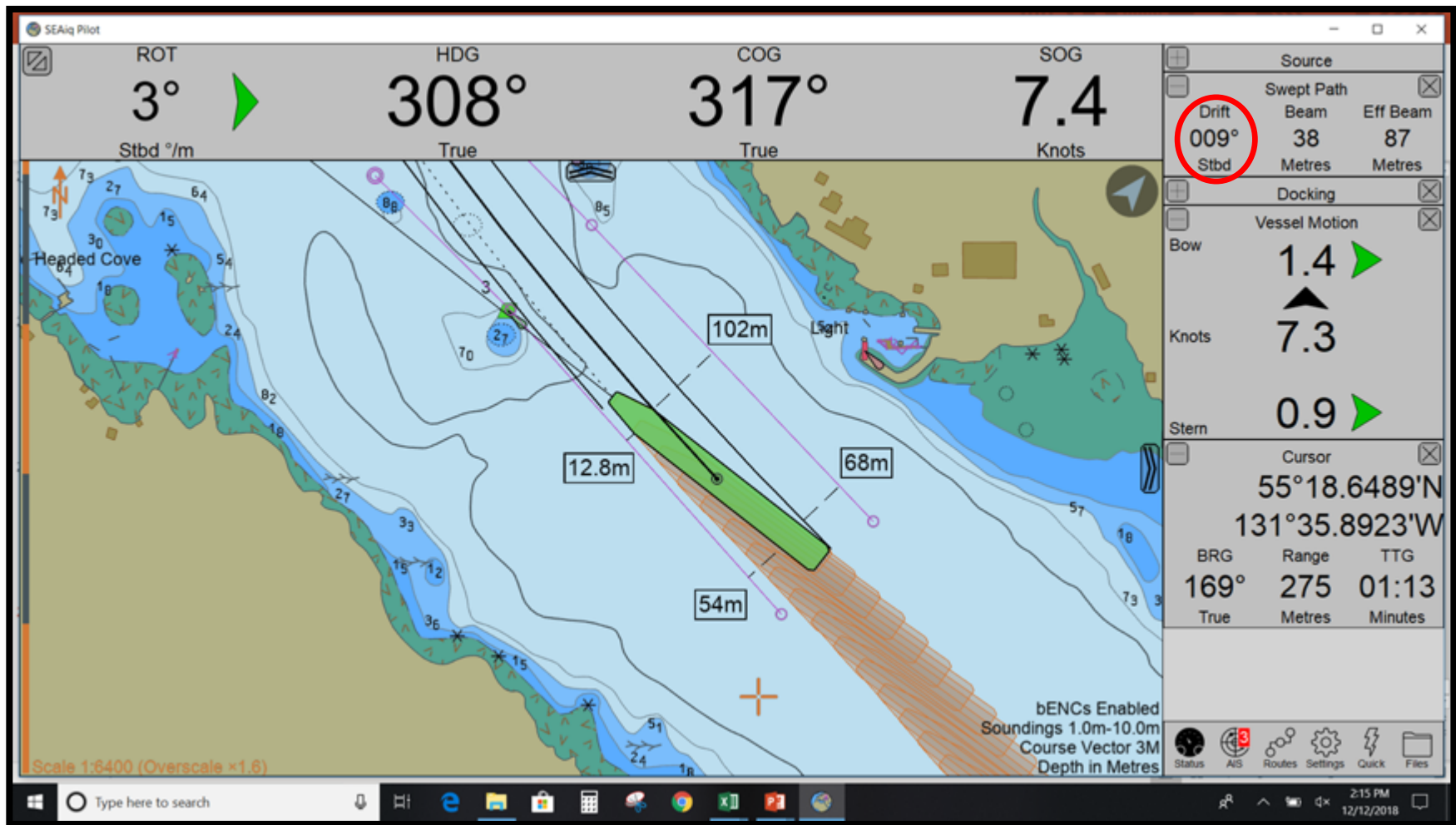
4.44 SW 20kn, no current, Ketchikan Arrival

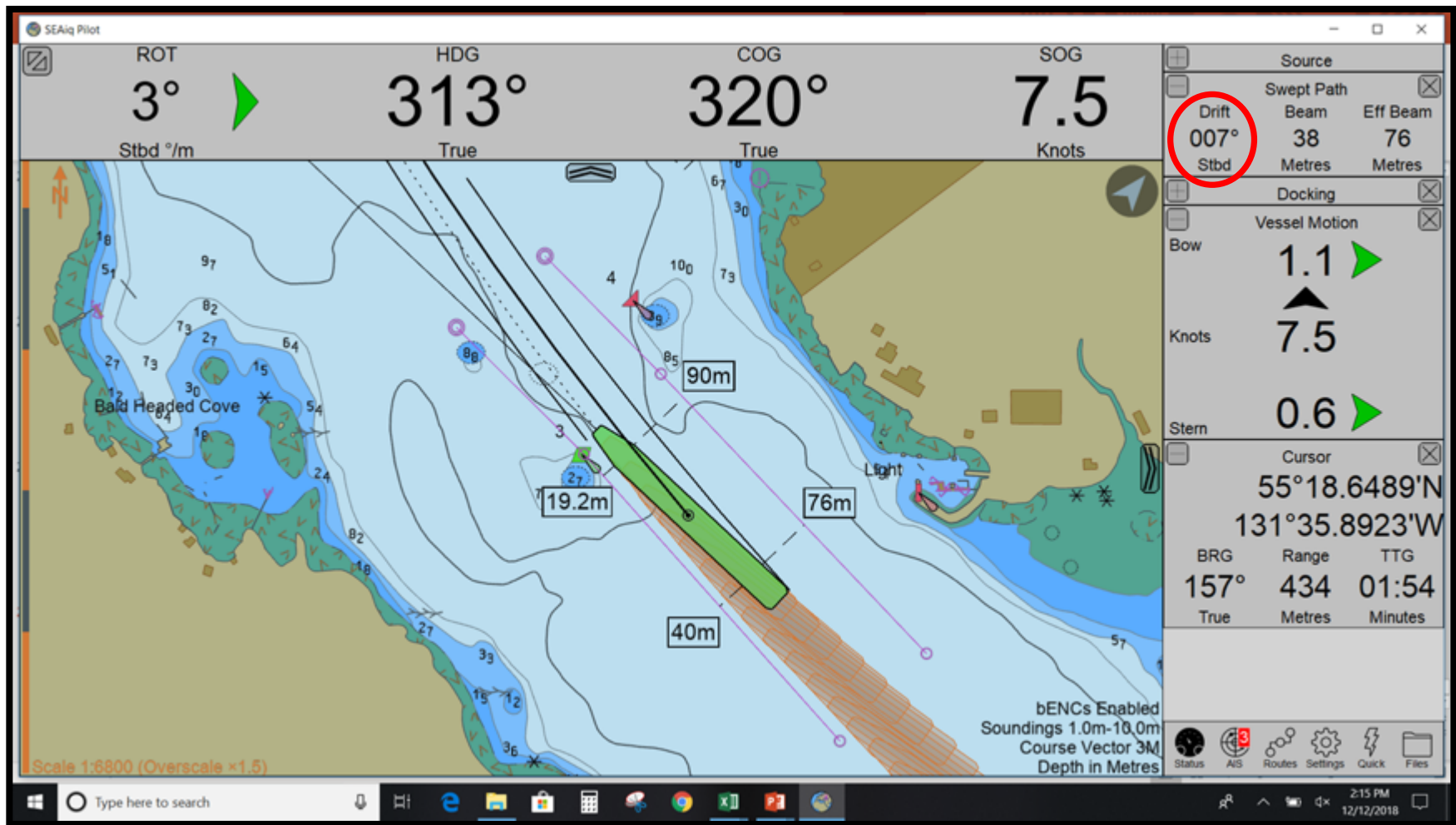
Wednesday 12/12/2018

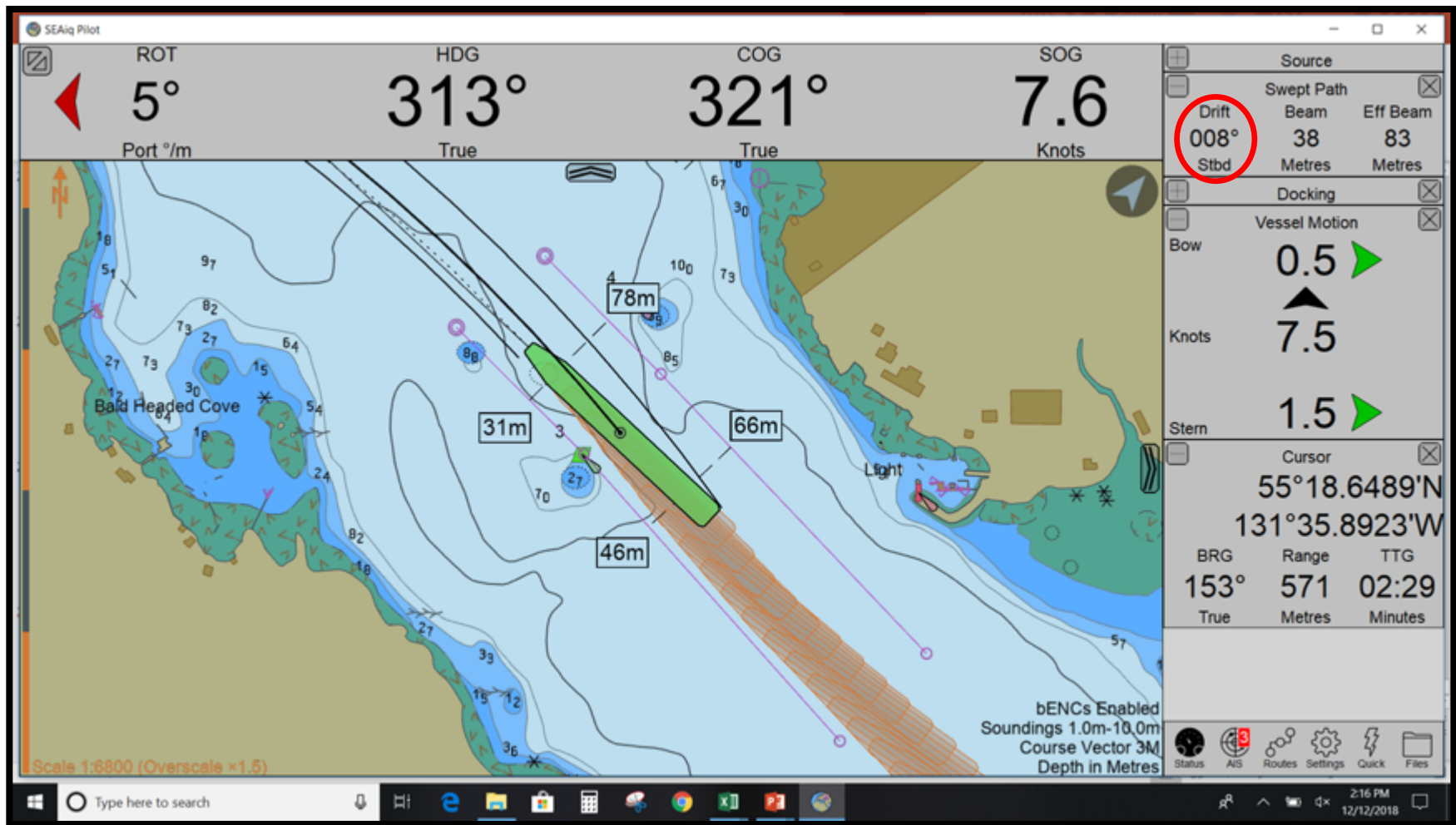
10th Run

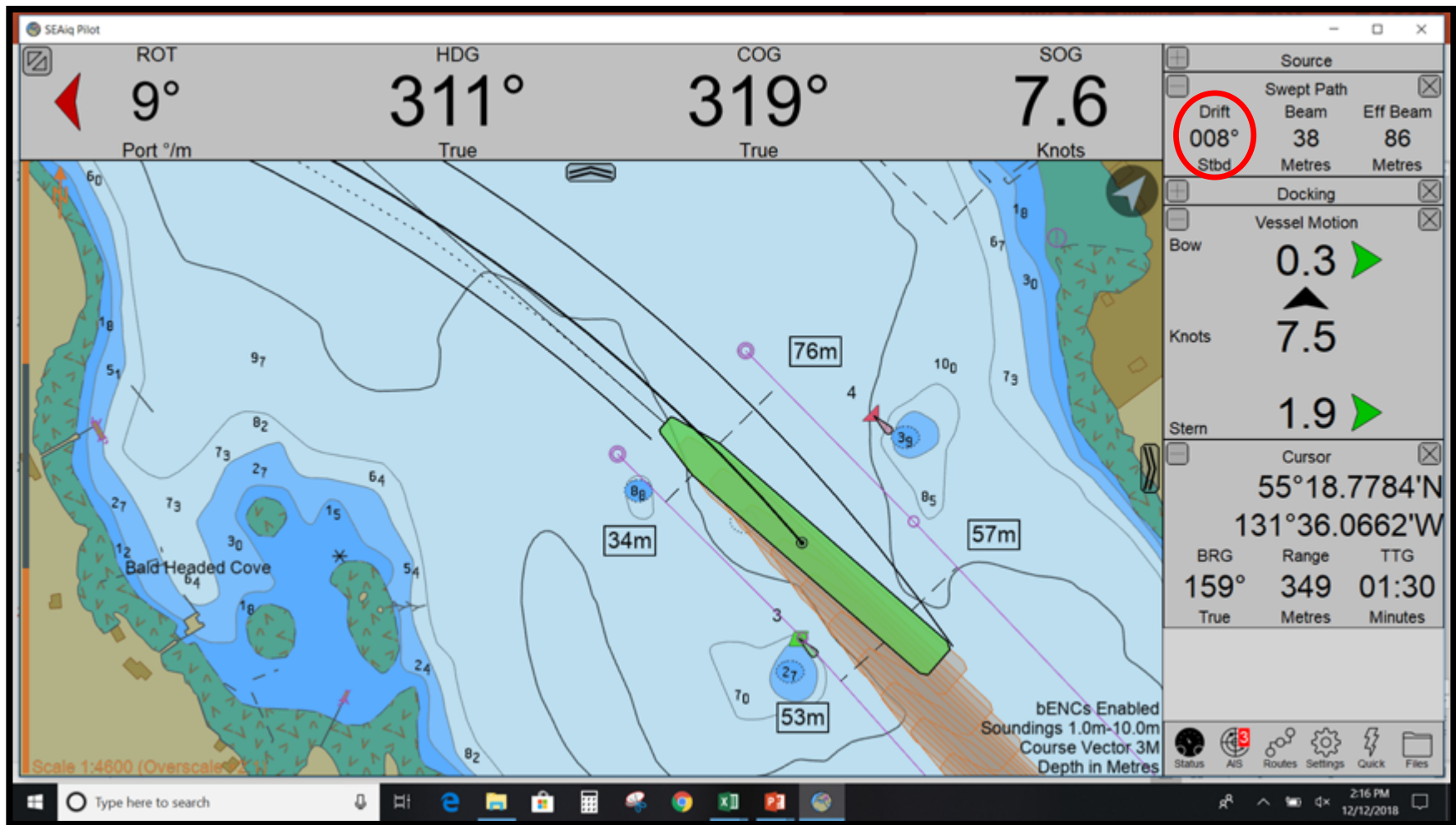


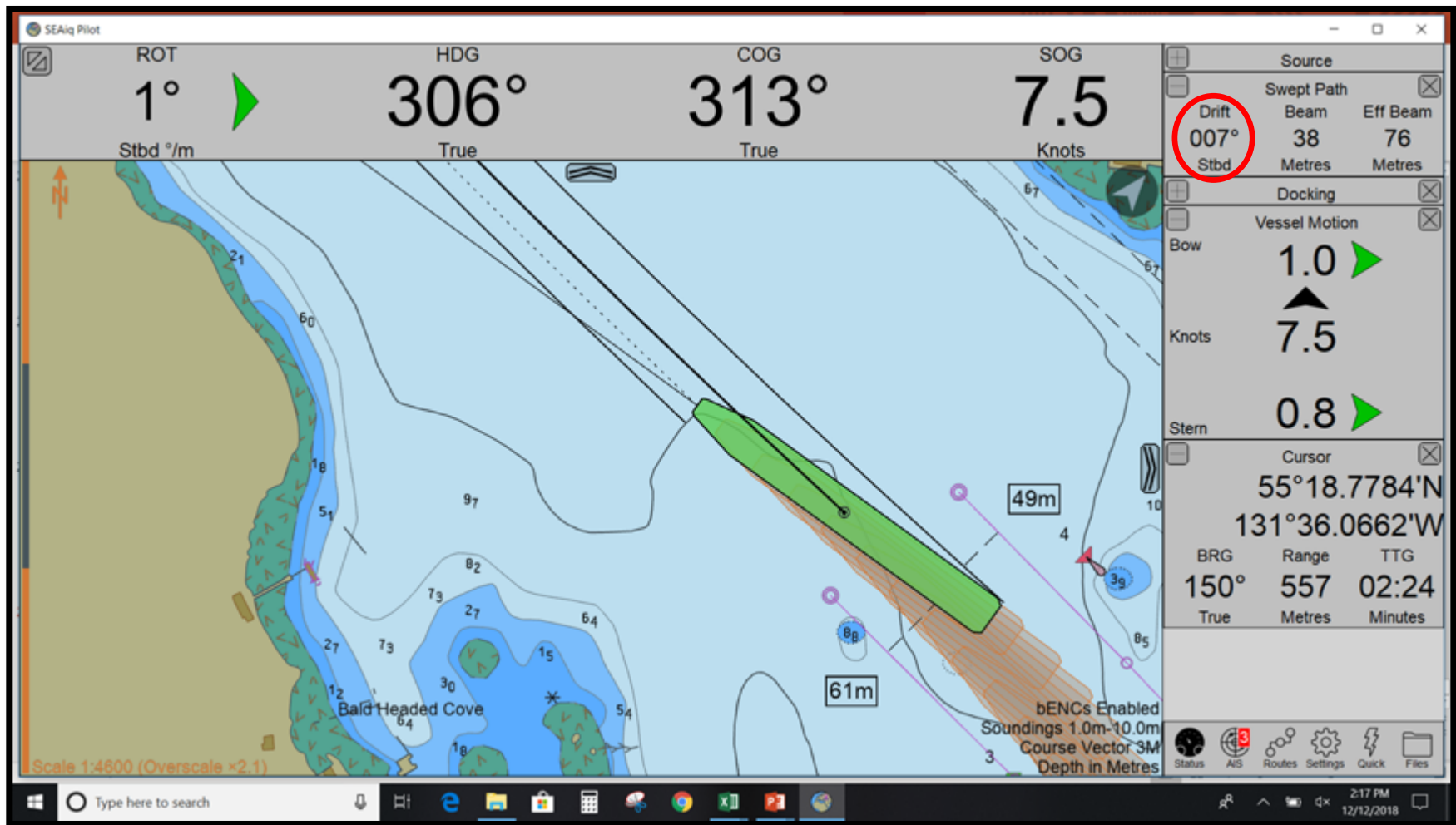












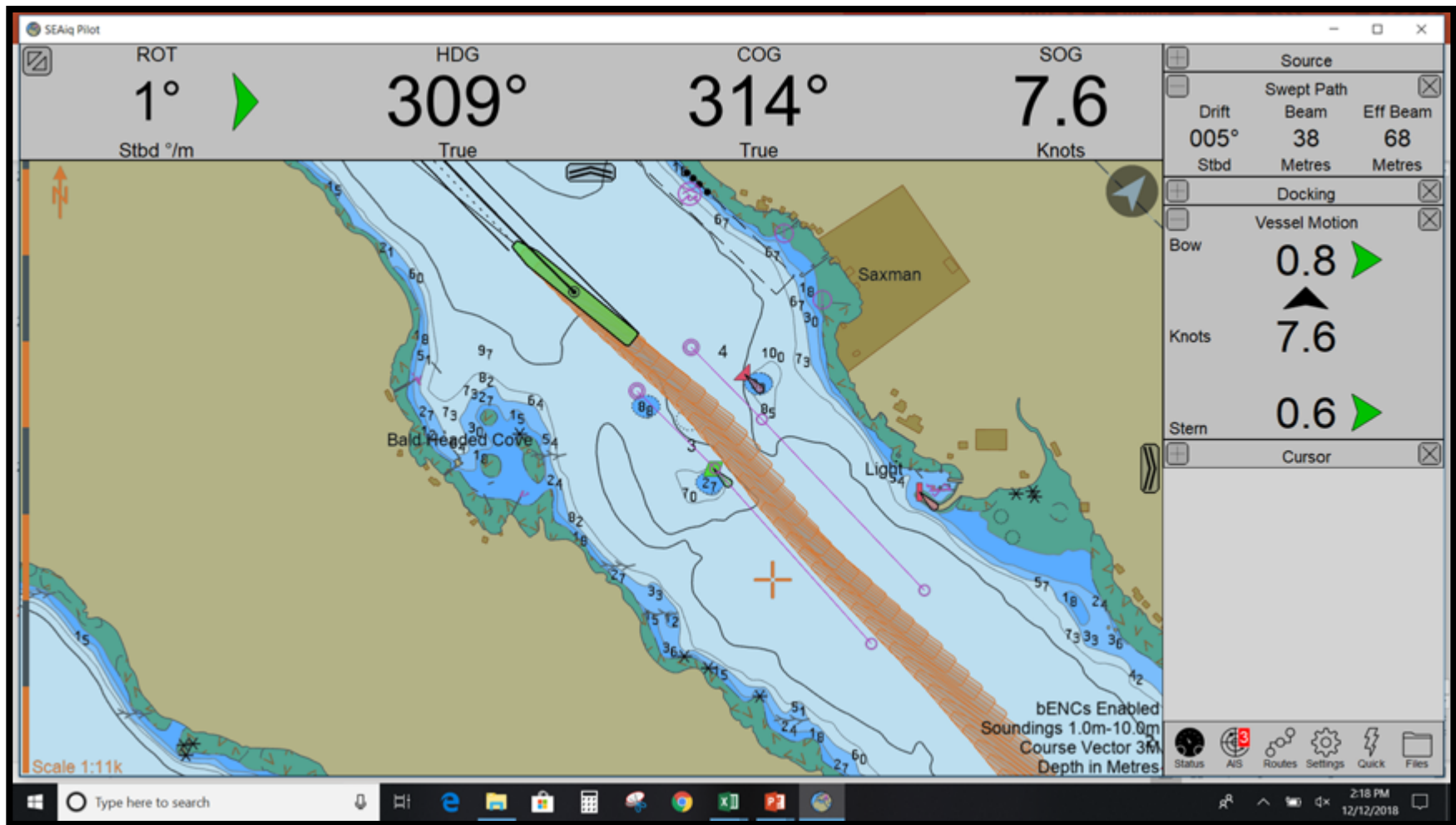


Figure 19: Royal Princess Alongside in Bonaire



End of Report